Logistics Management Institute

Choosing Between Public and Private Providers of Depot Maintenance
A Proposed New Approach

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Depot Maintenance: A Proposed New Approach

Executive Summary

The process used by the Department of Defense to decide whether the public (organic) or private (commercial) sector should perform depot-level maintenance has proven less than satisfactory. Both internal and external critics continue to call into question the comprehensiveness, consistency, and fairness of the process, as well as its effectiveness in mitigating performance risk. To some extent these critical concerns are legitimate; to some extent they reflect the parochial interests of the competing sectors' interest in retaining or obtaining workload. Regardless, the department does not have a process for making repair sector selection (RSS) decisions in which the various constituencies can place confidence.

Contributing to the present dilemma is the fact that historical rules of thumb—for example, defaulting to organic sources of repair in the absence of some compelling reasons not to—have become suspect or controversial or both. There are a number of reasons for this state of affairs. First, large-scale reductions in the cost of transportation and information relative to other factors such as inventory and labor have helped fuel a well-publicized shift to outsourcing in the commercial sector. Given the perceived benefits, it is small wonder that some senior DoD executives are pushing for greater outsourcing (i.e., privatization) of depot maintenance. Second, in the face of a decline in the acquisition of new weapon systems, original equipment manufacturers and their major subcontractors have shown a much stronger interest in this work than has historically been the case. Third, third-party maintenance providers have emerged with technical capabilities generally equivalent to those of the public depots. And fourth, the total amount of depot maintenance work has decreased since the end of the Cold War, with the result that the public and private sectors are vigorously contending for slices of a diminishing pie.

DoD has, at various times, used methods such as decision tree analysis (DTA), life-cycle cost analysis (LCC) and, most recently, the CORE methodology (a process for determining what workloads need to be part of DoD's core maintenance capability) to make RSS decisions. None has proved satisfactory. The DTA method, which depended on simple yes-no responses to a series of questions, was an unsophisticated approach to a complex problem that inherently lacks simple

answers. LCC analysis, by focusing exclusively on cost, ignores potentially crucial differences in relative performance risk. Although the current CORE methodology addresses risk and initially appeared to hold promise, in practice it has proved difficult to decide in any consistent way what needs to be in CORE and what does not. And, in general, all of the methods have narrowly focused on depot maintenance per se rather than considering depot maintenance as one component of a supply chain extending from factory to military end user.

To enable effective repair sector decisions, DoD must, first, base its decision process on a comprehensive understanding (i.e., a model) of the key elements in the decision and, second, apply that understanding fairly and consistently across the military services and over time.

We developed and recommend for use a model of the RSS decision that incorporates the following:

- ◆ Needs of the end-users of depot repair services (e.g., timeliness, low cost, quality)

- ◆ Characteristics of the two repair sectors such as adequate capability and capacity, scope and scale economy, and responsiveness that affect their ability to satisfy user needs

- ◆ Factors that determine the characteristics of the repair sectors. Such factors naturally group into three categories, based on whether they

    - ➤ are intrinsic to the nature of the repair sources themselves,

    - ➤ depend on the relationship between the repair source and the buyer of repair services, or

    - ➤ are a function of the repair work to be accomplished.

We identified 22 individual factors that are important to the repair sector selection decision and, ultimately, to the risk associated with satisfying end-user needs. Because there are a significant number of important factors and none lend themselves to simple yes-no answers, evaluation is too complex for a decision tree. To deal with this complexity, we developed an arithmetic modeling approach that combines individual factor evaluations into figures of merit that indicate the relative attractiveness (or risk) of the organic and private sectors.

As noted above, the second key ingredient of an effective RSS decision process is a means to apply the decision model fairly and consistently. Such a mechanism must meet two conditions. The first is that whoever does RSS evaluations has the needed training and experience to do them well. The second is that those who do evaluations are, and are perceived as being, free of conflicts of interest such as a personal or organizational stake in the outcome.

These two conditions are not met today. With regard to experience and training, as an example, initial RSS decisions are typically made by the staffs of system program offices. These individuals usually lack prior experience and training in such decisions. Even where there is prior experience, the lack of conflict provision generally cannot be satisfied. To solve these problems, we recommend the creation of an RSS decision support cadre reporting to the Defense Depot Maintenance Council. This cadre should

◆ be truly impartial regarding the outcome of RSS decisions and able to maintain the confidence of the competing constituencies as well as of internal and external process or decision critics;

◆ have the requisite education, technical training, market awareness, and policy perspective—in particular, they should be sufficiently senior to be on a peer level with their organic depot and commercial industry counterparts; and

◆ be constituted to assist the services in reaching depot maintenance repair sector selection decisions rather than taking the decisions out of their hands.

The RSS decision issue arises for both new workloads, such as those associated with new weapon systems and major modifications, and for existing workloads. New weapon systems and major modifications provide greater freedom of action, especially from a political perspective, than do existing workloads. For this reason, we recommend that our proposed approach be first applied to new workloads. Experience there will provide a basis for deciding how and when it should be applied to existing workloads.

In summary, our recommendations are as follows:

◆ A broader, balanced view of the repair sector selection decision will address the need for consistency and comprehensiveness.

Incorporate the 22 critical factors into policy on the RSS decision process.

◆ The use of arithmetic modeling in lieu of decision trees will provide a decision support mechanism equal to the complexity of the RSS decision.

Adopt an arithmetic modeling approach to support RSS deliberations.

◆ The use of a professional, impartial group to support RSS decisions will mitigate concerns about fairness and adequate consideration of risk.

Establish a cadre of government professionals to carry out RSS analyses in support of all the military services. Consider a special cell reporting to the Defense Depot Maintenance Council.

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Chapter 1
Introduction

PURPOSE AND SCOPE

The purpose of this study was to reexamine the Department of Defense process for deciding whether the public (organic) or private (commercial) sector should perform depot-level maintenance. In this report we will refer to the choice of public or private sector as the depot maintenance repair sector selection (RSS) decision.

The RSS decision occurs in two contexts: workload associated with new systems not yet in the inventory; and workload associated with systems already in the inventory, for which either the public or private sector might be the incumbent provider. The issues we raise and the broad recommendations we make are intended to be generally applicable to both contexts. However, the proposed decision model and methodology developed as part of the study were use-tested only on new systems.

BACKGROUND

Depot maintenance entails repair, rebuilding, and major overhaul of weapon systems (e.g., ships, tanks, and aircraft), parts, assemblies, and subassemblies. DoD currently expends about $12 billion annually for depot maintenance. Depot maintenance is performed by both the public (government-owned and -operated) and private sectors. DoD depots perform approximately 70 percent of the work, based on dollar value, and commercial sources 30 percent.

Numerous changes have occurred in the public and private sectors that affect this division of work. First, large-scale reductions in the cost of transportation and information relative to other factors such as inventory and labor have helped fuel a well-publicized shift to outsourcing in the commercial sector. Given the perceived benefits, it is small wonder that some senior DoD executives are pushing for greater outsourcing (i.e., privatization) of depot maintenance. Second, in the face of a decline in the acquisition of new weapon systems, original equipment manufacturers (OEMs) and their major subcontractors have shown a much stronger interest in this work than has historically been the case. Third, third-party maintenance providers have emerged with technical capabilities generally equivalent to that of the public depots. And fourth, the total amount of depot maintenance work has decreased since the end of the Cold War, with the result that the public and private sectors are vigorously contending for slices of a diminishing pie.

Not surprisingly, given the above background, the available procedures for allocating work between the public and private sectors are proving less than satisfactory. Both internal and external critics continue to call into question their adequacy, especially in terms of comprehensiveness, consistency, fairness, and effectiveness in mitigating performance risk. To some extent these critical concerns are legitimate; to some extent they reflect the competing sectors' parochial interests in retaining or obtaining workload. Regardless, the department does not have a process for making RSS decisions in which the various constituencies can place confidence.

What are the procedures for making repair sector selection decision methods? DoD has, at various times, used decision tree analysis (DTA), life-cycle cost (LCC) analysis and, most recently, the CORE methodology (i.e., a specific method used to decide what is and what is not core workload) to make RSS decisions. The DTA method, which depended on simple yes-no responses to a chain of questions, was an unsophisticated approach to a complex problem that inherently lacks simple answers. LCC analysis, by focusing exclusively on cost, ignores potentially crucial differences in relative performance risk. And, in any event, analysis of public and private options often do not indicate a clear cost advantage for either sector.[1] Although the CORE methodology addresses risk and initially appeared to hold promise, in practice it has proved difficult to decide in any consistent way what needs to be in core workload and what does not. For instance, all three military services entrust some frontline weapons to commercial sources of repair. This fact of life suggests that performance by federal government employees in organic maintenance depots is not always essential, but leaves unclear the circumstances where it is not essential. The final consideration is that, in general, all of the methods have narrowly focused on depot maintenance per se rather than considering depot maintenance as one component of a supply chain extending from factory to military end user.

STUDY APPROACH

Our approach to reexamining the RSS decision comprised four steps.

Survey of Related Research

First, we surveyed other relevant work in this area. Since 1993 there have been five major studies of depot maintenance: by the Joint Chiefs of Staff, the Deputy Under Secretary of Defense (Logistics), the Commission on Roles and Missions of the Armed Forces, the Defense Science Board Task Force on Depot Maintenance Management, and the Congressional Budget Office. There have also been a number of studies by the Logistics Management Institute (LMI), the RAND Corporation, the Center for Naval Analyses, Coopers and Lybrand, and others. Each of these studies contributed important insights but collectively, in our judgment, they were not a sufficient basis on which to design an improved RSS decision

process. To fill voids we conducted additional research in the areas of classical microeconomics, transaction cost economics, public choice theory, organizational theory, technology management, and supply channel behavior.

Interviews of DoD Personnel

Second, we conducted semi structured interviews of DoD management personnel in acquisition program management, depot maintenance management, materiel management, and weapon system operations.

Formulation of Decision Model and Process

Third, we synthesized the results of the literature search and the interviews to create a new RSS decision model and accompanying decision process.

DECISION MODEL

The initial result of the literature review and interviews was a lengthy list of candidate decision elements that ranged from customer needs such as low cost to more indirect considerations such as pipeline size, existence of more than one commercial source, and relative labor rates. We did not find a ready-made unifying theme for the various elements. However, it was possible to accommodate all elements in a three-tiered model (Figure 1-1) that interrelates

- ◆ customer needs,

- ◆ characteristics of alternative sources of repair, and

- ◆ three sets of determining factors (a total of 27 factors, initially), which either

  - ➤ are intrinsic to the nature of the repair sources themselves,

  - ➤ depend on the relationship between the repair source and the buyer of repair services, or

  - ➤ are a function of the repair work to be accomplished.

Because there are a significant number of important factors and none lend themselves to simple yes-no answers, evaluation is too complex for a decision tree. Accordingly, we developed an arithmetic approach that combines individual factor evaluations into figures of merit, which indicate the relative attractiveness (or risk) of the organic and private sectors.

Figure 1-1. RSS Decision Model
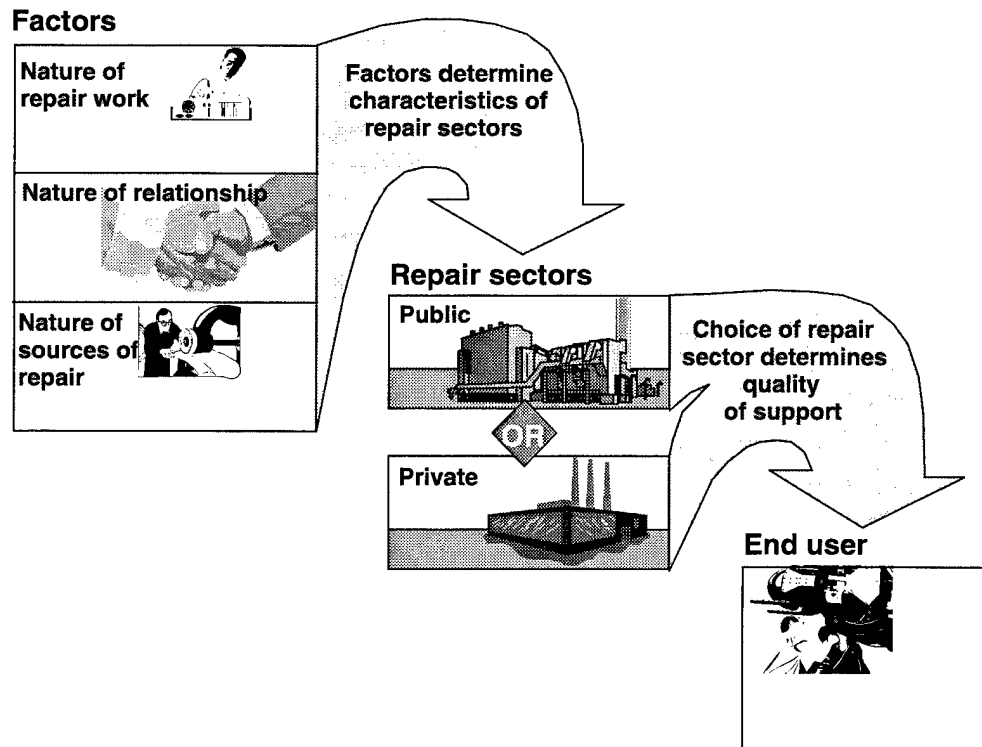
DECISION PROCESS

The decision process, illustrated in Figure 1-2, was based on an integrated process team (IPT) approach; in this case IPTs comprised both government and industry representatives. The primary motivation for this design was to incorporate a mechanism for countering the inevitable biases that result when individuals with a stake in an outcome are asked to make evaluations.

The basic decision process—evaluation of established factors, integration in a simple mathematical model, interpreting results, followed by holistic assessment—intentionally borrows from successful methods used for contract source selection. The mathematical model combines a number of disparate and often subjective evaluations into a much smaller set of figures of merit that are relatively easy to interpret. However, precise appearing numerical scores can also give the results more credence than they deserve—hence the holistic assessment is an essential part of the decision process.

Figure 1-2. RSS Decision Process
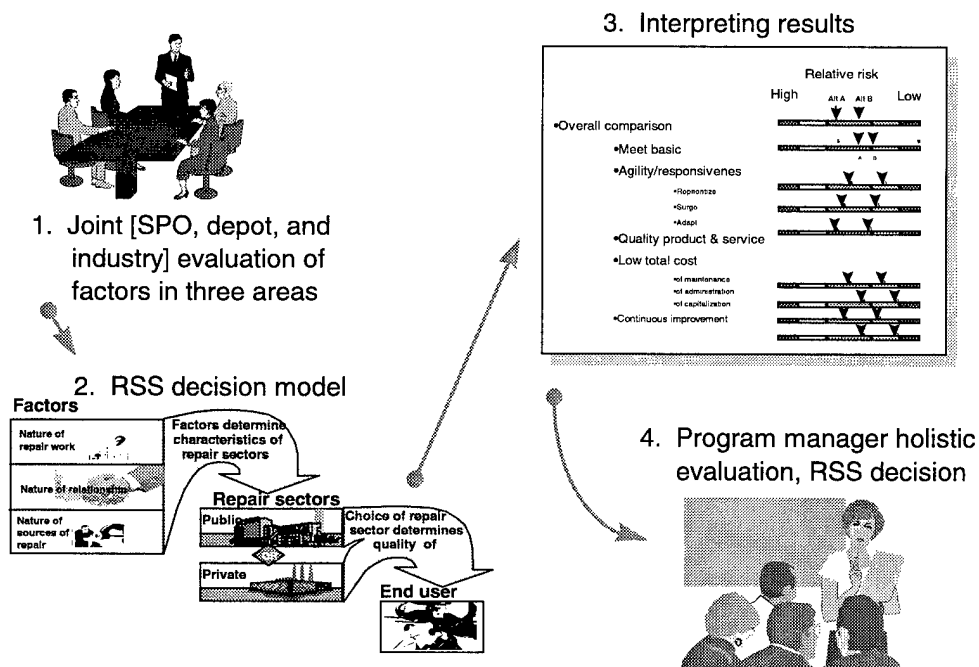
Test of the Model and Process

As the fourth step, we use-tested the decision model and process on three different V-22 aircraft workloads. In order to use-test the decision model:

◆ We implemented the model in a spreadsheet.

◆ Next, the importance of each customer need was initially assigned by LMI analysts and then verified as reasonable during field interviews. LMI, using a focus-group, also developed a preliminary set of weights linking customer needs to the characteristics of repair sector choices and another set of weights linking characteristics of choices to determining factors.

◆ Using the decision model with LMI-developed weights, the V-22 system program office (SPO) convened IPTs to conduct RSS evaluations on the T-406 engine, the V-22 forward-looking infrared scanner, and the V-22 Cockpit Control Feel and Drive actuator.

RESULTS

In general, IPT participants were comfortable with the proposed RSS decision model and saw it as providing value-added structure to the RSS decision process. In fact, the process helped the V-22 SPO reach and defend a decision on the T-406 engine. However, the results of the use-tests supported only 22 of the

proposed factors (Table 1-1). We recommend these 22 factors be incorporated into the policy on RSS decisions.

Table 1-1. RSS Decision Factors

Category	Decision factor
Nature of the repair work	• Relative size versus potential source of repair • Demand predictability • Design stability • Repair process dependence • Absence of proprietary data issues
Nature of the relationship with potential sources of repair	• Flexibility of relationship • Scope of relationship • Policy on related functions such as engineering and materiel management • Policy on lot sizes • Policy on repair parts management • Incentive structure
Nature of the sources of repair	• Availability of more than one source • Availability of sources with complementary workload • Interest by potential sources • Reserve capacity for this work • Capacity in excess of that needed for workload • Availability of skilled labor • Stable labor relationships • Customer knowledge • Product knowledge • Process knowledge • Implementation of closed-loop Manufacturing Resource Planning (MRP-II)-based management methods

The use-tests indicate that the work required for an IPT to subjectively evaluate 22 factors is not exorbitant using the model we developed. An IPT meeting of 4 to 5 hours was sufficient even for complex workloads, given adequate but not unreasonable preparation.

The concept of capacity, however, will require further research. The two-part construct we used (reserve and excess capacity) presented difficulty in all tests. It is

possible that measuring capacity may require more effort than the benefits warrant. If so, reserve and excess capacity could be dropped from the decision model.

Of equal, if not greater, importance is that the IPT format did not fully control bias. Although gathering both sides to an RSS decision at the same table has its merits, the tests revealed some unresolved problems:

◆ The potential for one or more strong individuals, particularly those intent on introducing bias, to dominate the session.

◆ The potential for opposing representatives to not be peers from the standpoint of education, technical training, or experience. As an example, there is a potential that industry representatives will be more sophisticated and better prepared than their government counterparts.

◆ A lack of relevant information. When people know which depot or commercial source of repair would likely receive the work, finding individuals who can knowledgeably assist in the factor evaluations is reasonably straightforward. This is not the case if the organic and commercial sources are up in the air.

◆ RSS evaluations are typically made by the staffs of SPOs. These individuals may lack prior experience in such decisions or any related training. Further, once they make the investment in mastering the process they may not have the opportunity to participate in such decisions again.

To identify alternatives to an IPT, we looked for promising analogues in other spheres. Finding such an analogue was not difficult. The central problems of the RSS decision—providing for experienced and trained staff, uncovering all of the relevant information, assuring freedom from conflict of interest—occur also in the context of major business transactions such as mergers and public offerings. There, these problems are addressed through what is known as a "due diligence" procedure. The basics, if not necessarily the details, of due diligence are applicable to the RSS decision: due diligence succeeds when it is performed by investigators who have the requisite training and experience and are also free from conflicts of interest. Accordingly, we recommend that DoD borrow from the due diligence practice and create an RSS decision support cadre. This cadre could notionally report to the Defense Depot Maintenance Council. Further, it should be constituted such that it is

◆ truly impartial regarding the outcome of RSS decisions and able to maintain the confidence of the competing constituencies, as well as critics of the process or decision;

◆ able to bring to the RSS analyses the requisite education, technical training, market awareness, and policy perspectives—in particular, cadre staff

should be sufficiently senior to be on a peer level with their organic depot and commercial industry counterparts; and

◆ an aid to the services in performing RSS decisions, but does not take the decisions out of their hands.

LIMITATIONS

The evaluation approach described in this report focuses on the relatively immediate requirements of the repair customer and what it takes to satisfy those requirements. This approach excludes a number of potentially important considerations. Among them are the political considerations mentioned above, as well as equity considerations (for example, effects on the government or contract work force of shifting workload from one to the other). Additionally, because the approach is inherently incremental, workload-by-workload, it does not address issues relating to long-term strategic posture. Finally, as mentioned earlier, the proposed approach has been tested only on new workloads.

End Notes for Chapter 1

[1] Office of the Under Secretary of Defense for Acquisition and Technology, *Report of the Defense Science Board Task Force on Depot Maintenance Management*, April 1994, p. F-38;

David R. Warren, *Uncertainties and Challenges DoD Faces in Restructuring Its Depot Maintenance Program*, Statement before the Subcommittee on Military Readiness, Committee on National Security, U.S. House of Representatives, 18 March 1997, p. 25.

Chapter 2
Designing a New Decision Model

OVERVIEW

As described in Chapter 1, DoD has, at various times, used methods such as decision tree analysis (DTA), life-cycle cost (LCC) analysis, and, most recently, the CORE methodology to make RSS decisions. None has proved satisfactory. DTA, which depends on yes-no responses to a series of questions, was an overly simplified approach to a complex problem. LCC analysis, by focusing exclusively on cost, ignores potentially crucial differences in relative performance risk. Although the CORE methodology was more encompassing and held promise, in practice it has proved difficult to decide in any consistent way what needs to be in CORE and what does not.

Developing a new approach to the depot RSS decision requires two considerations. The first is a reasonably comprehensive statement—i.e., a model—of the key elements of the RSS decision itself. The second is a means for applying the decision model fairly and consistently across the military services and over time. This chapter develops the structure for and candidate factors to be included in the new model; Chapter 3 then develops a process for applying the model. The model and process are refined in Chapter 4 based on the results of trial applications.

Review of DoD experience to date, related trends in commercial industry, and the research literature resulted in a lengthy and heterogeneous list of candidate issues and factors that could bear on the RSS decision. Although we did not find a ready-made unifying structure for these various factors (actually, there were multiple and conflictual unifying structures), we were able to accommodate them in a fairly simple model with three basic elements (Figure 1-1). The three elements are:

◆ Needs of the end users of depot repair services (e.g., timeliness, low cost, quality)

◆ Characteristics of the two repair sectors relevant to satisfying user needs (e.g., adequate capability and capacity, scope and scale economy, responsiveness)

◆ Factors that determine the characteristics of the repair sectors. These factors

➤ are intrinsic to the nature of the repair sources themselves,

> ➤ depend on the relationship between the repair source and the buyer of repair services, or

> ➤ are a function of the repair work to be accomplished.

The balance of this chapter develops each of these elements.

NEEDS OF END USERS

The basic and well-documented needs of the end users of depot repair services are to minimize operational risk (through assured readiness and sustainability) and control costs. However, readiness and sustainability are relatively broad concepts, and it is not necessarily clear what is meant by the term "cost." Hence, it is necessary to break these broad requirements down into more specific subrequirements. The body of literature on depot maintenance suggests five basic depot maintenance customer requirements that, if satisfied, minimize risk and control cost:

- ◆ Ability to meet basic demand

- ◆ Agility and responsiveness to changing demand

- ◆ Quality product and service

- ◆ Low total cost

- ◆ Continuous improvement of both product and service.

Below we describe each of these requirements and show, by reference to policy and previous studies, why they are legitimate depot maintenance requirements.

Ability to Meet Basic Demand

The ability to meet basic demand means remanufacturing reparables at the average or steady-state rate expected in peacetime. It supports the requirement to keep weapon systems in a high state of operational readiness during peacetime—i.e., to support peacetime training and normal peacetime operational tasks, such as alert and airlift/sealift, at their planned operational tempos. However, we use the narrower construct of meeting demand (for remanufacture of reparables) rather than readiness, because there are many influences on readiness, of which ability to remanufacture reparables at an adequate rate is only one.

Agility/Responsiveness

Agility/responsiveness is the ability to satisfy an unanticipated change in requirements. There are three types of changes in requirements:

◆ Surge

◆ Changes in priorities

◆ Qualitatively different requirements.

SURGE

Probably the most familiar responsiveness-related requirement is an overall increase in demand—generally referred to as surge. Surge was an assumed requirement during the Cold War. A case can be made that, while surge was an important consideration for a protracted conflict, it may not be during a contingency.[1] However, because there is not yet a consensus on this issue and because there was evidence of surge during the Persian Gulf conflict in all three services,[2] we retain it as a customer requirement.

CHANGES IN PRIORITIES

Of potentially more critical importance are changes in priorities, particularly for high-technology weapon system components such as electronics and turbine engines. A growing body of research indicates that constant changes in depot maintenance priorities should be considered the norm rather than the exception and that there is a significant penalty if a source of repair cannot respond to them.[3] One study[4] summarized the situation well when it concluded that

◆ the variability of resource demands thwarts accurate forecasting even in peacetime;

◆ wartime forecasting is even more difficult because, in addition to the inherent problem of demand variability (which gets worse in wartime), it is unlikely that the real contingency will ever match the planning assumptions that were made; and

◆ during a contingency, there are unpredictable threats to repair, supply, and transportation.

QUALITATIVELY DIFFERENT REQUIREMENTS

Unanticipated increases and decreases in steady-state demand rates are not the whole story; qualitative changes in requirements are also important. An example would be the rapid dispatch of field teams for in-theater and crash or battle damage repair.

Quality Product and Service

A third customer requirement is quality.[5] Quality can take on a range of meanings, from the ability to satisfy customer needs in the broadest sense to the narrower sense of compliance with performance or material specifications.[6] In this context the broader meaning would be potentially confusing, since it would include such considerations as agility and responsiveness. To avoid this potential confusion, we will define quality to include product quality (performance and materiel specifications) and service quality.

Low Total Cost

Virtually all of the literature on depot maintenance and almost all interviewees cited cost as an important consideration in making source of repair decisions.

Generally, however, and as Camm has noted, cost is narrowly defined when used as a criterion for the source of repair.[7] Typically it encompasses only the cost of repair (the sum of direct labor, depreciation on capital plant, and other depot indirect costs).[8] Absent from the usual definition is the investment in reparable inventory to fill the pipeline to and from the source of repair. This cost is significant and is affected by the characteristics of the source of repair.[9] For this reason we explicitly include pipeline costs.

There is another, more subtle, type of cost that is also generally assumed away—the cost of administration, by which we mean the costs of writing an initial contract, negotiating changes in performance to contracts that already exist, and monitoring performance.[10] (In this case the word "contract" is a generic term that applies to both legal contracts with commercial sources of repair and to the more informal arrangements with DoD maintenance depots.) We noted above in the discussion on agility and responsiveness that it is impossible to forecast demands with exact accuracy, particularly in a contingency. In the case of DoD organic repair (assuming effective organizational arrangements), such an inability to forecast might not matter much because, as with any internal command organization, it is at least nominally possible to rapidly adjust output as changes in requirements become known. It is generally harder, and potentially much harder, to provide for such contingent performance through a formal contract mechanism.

Need for rapid adjustment in output (contingent performance) is the fundamental rationale for the DoD CORE policy and for viewing DoD internal CORE depot capability as a "ready and controlled" source. Although not usually recognized as being so, the CORE policy is well grounded in economic transaction cost theory[11] and the literature on supply chain management.[12] Commercial firms adopt similar policies to guide their make-or-buy decisions.

However, that is not to say it is impossible to provide for contingent performance from a commercial source of repair, or to protect against potential price gouging

when negotiating follow-on contracts when there is a single seller. These things can be provided for, but the administrative cost of doing so is normally larger than for using an organic source of repair.

Given the above considerations, we define total cost to include the following:

♦ The cost of maintenance, per se, including depot noncapital indirect costs

♦ Capital costs of facility and pipeline. As capital costs, these costs are generally one-time, start-up costs.

♦ The cost of administration.

Continuous Improvement of Product and Service

The fifth, and last, requirement is continuous improvement of product and service. It is generally absent from previous studies of depot maintenance. However, it is not a novel concept and has received much emphasis in the manufacturing literature during the last decade as a legitimate user requirement. We include it here because of its potential, if not fully recognized, importance to DoD depot maintenance.

Summary of Customer Requirements

In summary, then, these are the five customer requirements:

♦ Meeting basic demand.

♦ Agility/responsiveness in providing for

➤ reprioritization,

➤ surge, and

➤ new and qualitatively different requirements.

♦ Quality product and service.

♦ Low total cost of

➤ maintenance, per se,

➤ administration, and

➤ start-up capitalization.

♦ Continuous improvement of product and service.

CHARACTERISTICS OF THE REPAIR SECTORS

The section above identified five basic user requirements. How well they are satisfied will depend on the characteristics of the chosen source of repair. Before proceeding with a discussion of the characteristics of the choices, it is worthwhile to recall that in the context of this study the choice is not between a specific firm and specific government depot, but the more general choice between organic and commercial repair sources—where any of a number of commercial firms or government depots could be the actual future provider.

In this section we develop 10 repair sector characteristics that could determine how well customer requirements are met. It is certainly possible to generate a list with more or less than 10 characteristics. The list here results from balancing three goals:

♦ Creating a list short enough to be of practical use

♦ Being specific

♦ Keeping the characteristics from overlapping.

The 10 characteristics are shown in summary form in Figure 2-1. In the text that follows we define the characteristics and show, primarily by citing customer requirements, why they are relevant to the source of repair decision.

Figure 2-1. Characteristics of Repair Sector Choices

- Adequate capability and capacity
- Scope and scale economy
- Overhead costs
- Non-value-added effort
- Extraordinary profits, fees, earnings
- Responsiveness to changing needs
  - Reprioritization capability
  - Surge capability
  - Task flexibility
  - Customer linkage
  - Administrative ease

- Incentive to improve
- Work stoppage protection
- Pipeline size (quantity and time)
  - Order and ship (administration)
  - Repair cycle at source of repair
  - Material movement (user to SOR and return)
- Output quality
  - Of product
  - Of service

Adequate Capability and Capacity

Two of the customer needs were ability to meet basic demand and the agility and responsiveness to satisfy unanticipated changes in demand. In part these are capability and capacity issues where, consistent with the theory of constraints, capability and capacity are both zero until each significant production constraint has been removed.[13] At that point there is capability and some (not necessarily enough) capacity.

To increase capacity, more resources have to be provided at the points that constrain the production process. Hence adequate capability and adequate capacity entail having in place both the technical processes necessary to repair what is needed (capability) and also the resources to assure production at required rates (capacity). Capacity is important to both the ability to produce when needed and to cost. If the volume of goods produced falls below capacity, then costs per unit rise rapidly, assuming no alternative use of resources.

Scale and Scope Economy

We established earlier that control of costs is an important user need. Two important characteristics of the components of military weapon systems are their low individual demand (failure) rates[14] and, as we will also discuss later, the significant variability of those rates.[15] Low repair volume per reparable item (i.e., part-numbered or stock-numbered item) makes it inherently difficult to operate efficiently if repairs are performed at many individually small locations. DoD depots have sought efficiency by centralizing repairs for individual reparable items at one or at least a small number of locations and by establishing facilities that can repair a broad range of complementary items. The first approach is generally described as scale economy and the second as scope economy. In 1985, Embry et al. held that no commercial aviation sources of repair had broad scope,[16] but the same is not necessarily true today.[17] The major commercial shipyards, of course, have traditionally had a broad scope of repair capabilities.

Overhead Costs

Direct costs accrue from the unit being produced.[18] The three major components are direct labor, direct materials, and purchased parts. Overhead (or indirect) costs are all other costs incurred in accomplishing repairs and running the business. Examples are management salaries, utilities, equipment depreciation, and training. Because control of overhead is a significant issue, it has figured prominently in just about every recent look at depot maintenance. What makes it particularly pertinent to the repair sector selection decision is that the overhead rates of various potential providers of depot maintenance are believed to differ significantly.

Non-Value-Added Effort

The distinction between direct and indirect costs comes from accounting. There is a second and more recent accounting distinction between value-added and non-value-added effort. Value-added effort "is the contribution made by an operation or a plant to the final usefulness and value of a product as seen by the customer."[19] Non-value-added effort, which may be either direct or indirect in the traditional sense, is effort that adds to cost but does not contribute to value as seen by the customer. Obvious examples for depot maintenance would be replacing parts not subject to wearing out, inspecting and testing parts (such as electronics) where incipient failure cannot be predicted, and repairing features that the user does not want or use. Non-value-added effort patently exists in depot maintenance as it does in any manufacturing enterprise, particularly in the form of "nice-to-have" services. Because the extent of unnecessarily added cost may depend on the repair sector selected, we include non-value-added effort as a repair sector characteristic.

Extraordinary Profits, Fees, Earnings

When a product or process entails significant sunk costs that are specific to either the user's or producer's operation, the party with the least sunk costs has an opportunity to take advantage of the other.[20] DoD weapon systems for which there are no commercial equivalents are such sunk costs and might offer such an opportunity, when there is scant choice for repair capability in the commercial sector other than by the OEM. Hence there is a legitimate basis for fearing exploitation by opportunistic suppliers.[21] (This issue is referred to in the transaction cost literature as the asset specificity problem—recognizing the situation where assets are specific to a particular use and not easily used for some alternative purpose.)

As an example, if there were only one commercial source of depot maintenance for B-2 aircraft, then that commercial source would, at least notionally, have the leverage to extract larger payments for repair services than if there were more sources. (This problem is actually a two-edged sword: if a commercial firm invests in a repair capability for which the only customer is DoD, then DoD gains leverage. Here we are primarily concerned with situations where the government is at risk.) It is not a given, however, that suppliers will act opportunistically when offered the chance, and each situation merits individual consideration. For all of these reasons, extraordinary profits, fees, and earnings are considered as a characteristic to be evaluated.

Responsiveness to Changing Needs

Consistent with the user's needs for responsiveness, there are five components to a supplier's actual responsiveness:

◆ Reprioritization capability

◆ Surge capability

◆ Task flexibility

◆ Customer linkage

◆ Administrative ease.

Reprioritization, surge, and task flexibility correspond to the customer needs discussed earlier. Customer linkage and administrative ease are further explained below.

CUSTOMER LINKAGE

There is obvious credence to the notion that warfighters and the providers of depot maintenance need to be closely linked. In fact, the 1993 Office of the Secretary of Defense evaluation of depot maintenance management options used as a criterion the effect on the linkage between the warfighter and depot maintenance.[22] We specifically include that linkage as an attribute of repair sectors because opponents of logistics outsourcing caution that outsourcing will lessen direct contact with customers.

ADMINISTRATIVE EASE

In the information processing view of interorganizational relationships, for production to be effective the information processing capabilities of a production structure (one organization or a combination of organizations) has to match its information processing needs. In general, the required capabilities are more complex, and resulting costs are larger, for contractual arrangements between organizations than for administrative arrangements within an organization.[23] This is what the Office of the Secretary of Defense (Logistics) was getting at in its integrated management study, when it said that "public sector depots, *under the direct control of the military*, are organized to respond rapidly to the full scope of maintenance requirements to be expected in a war" (emphasis added).[24]

The more complex capabilities needed to administer production, if it is done commercially rather than organically, normally cost more and are more difficult to put in place. Hence our coining the term administrative ease and including it as a characteristic of the repair sector. Note that administrative ease and incentive to

improve (below) can pull in opposite directions: competition-based incentives come at the cost of increased administrative difficulty.

Incentive to Improve

We noted earlier that continuous improvement is an important, if under-recognized, customer requirement. Since improvement does not just happen but is caused, understanding the incentives to improve can be important, if different sources of repair have different incentives.

There can be such differences. In particular, when the possibility of "exit"—choosing another supplier—is real, then management is more likely to take seriously the needs of customers than when there is no alternative supplier. Such differences in incentives could show up when comparing a sole-source public depot with competed contract support, or if the choice is between sole-source and competitive commercial support. Competition can create strong incentives to simplify organizations, use multiskilled workers, and eliminate unnecessary work in order to win work. Organization size also affects incentives, with incentives generally being impaired in larger organizations.[25]

Because incentive to improve can differ between a source of repair that has competition and one that does not, or between a large organization and a smaller one (and probably for other reasons as well), incentive to improve is a relevant characteristic for the repair sector selection decision.

Work Stoppage Protection

Protection from work stoppage or disruption is one of the arguments for preserving the depot maintenance CORE capability. It includes protection from both the effects of strikes and high switching costs, the costs associated with switching from one supplier to another in the event the first supplier is not satisfactory.[26] These costs need not be economic but can include, for instance, an impeded ability to effectively wage war. The implicit assumption in the CORE policy is that organic facilities can provide this protection more readily than can commercial ones. It makes sense, then, to explicitly include this as a feature of alternative repair sectors.

Pipeline Size (Quantity and Time)

Under our discussion of user needs, we noted that low total cost properly includes investment in pipeline. Pipeline has been defined as the distance between supplier and consumer, measured in days of supply; thus the concept of pipeline involves dimensions of both quantity and time.[27] With regard to repair sector decisions, required investment in pipeline is a function of the quantity of reparables required

to be in the pipeline. Here we use the term "pipeline" in a general sense to encompass all reparables, whether or not they are in transit.

Defined this way, the pipeline comprises two segments. One is a forward, to-the-customer, order-fulfillment segment (measured in terms of order and ship time).[28] The second segment is usually called the repair cycle (it is actually a half-cycle). It includes retrograde movement, repair-related administration, and the repair process itself.[29] In order to better align the pipeline segments with the concept of administrative ease and its related transaction costs, we will redefine the segments in terms of activity rather than sequence, so that they comprise

- in-transit movement (both user to repair location and return);

- administration—the "order" part of the classical order and ship segment, as well as administration associated with repair process induction; and

- the repair process at the source of repair (depot or contractor facility).

Output Quality

Earlier, we established the customer requirement for quality and defined the concept to include both product and service. This implies fairly obvious output measures for the source of repair. Hence we include, as attributes of the repair sector, output quality

- of product and

- of service.

FACTORS THAT DETERMINE REPAIR SECTOR CHARACTERISTICS

At the start of this chapter we identified five needs of the end users of depot repair services: the ability to meet basic demand; agility/responsiveness; quality product and service; low total cost; and continuous improvement. We then discussed the characteristics that determine how fully a repair sector can meet customer requirements.

The characteristics of the repair sectors, in turn, are determined by another set of factors that we now will describe. We will argue that there are three evident classes of such factors:

- *Factors related to the nature of work itself.* Although these factors are a function of the work to be performed rather than the source of repair, they may make one repair sector more attractive than another.

◆ *Factors describing the relationship with the sources of repair within a repair sector.* This second category of factors, which includes considerations such as incentive structure, is primarily a function of policy. This category may also make one repair sector more attractive than another if, for instance, the policy regarding one repair sector differs from the policy that affects another.

◆ *Factors related to the sources of repair themselves.*

Figure 2-2 summarizes the three classes of factors.

Figure 2-2. Determining Factors

● **Nature of repair work itself**
  - Workload size vs. size of market
  - Workload size compared to the workload at sources of repair
  - Demand predictability
  - Design stability
  - Technology renewal rate
  - Uniqueness of technology
  - Repair process dependence
  - Availability of engineering data
  - Absence of proprietary data issues

● **Nature of relationship with sources**
  - Type of relationship (flexible vs. inflexible)
  - Scope of relationship
  - Policy on related functions
  - Policy on lot sizes
  - Policy on repair parts
  - Incentive structure

● **Nature of sources**
  - Availability of more than one source
  - Availability of sources with complementary workload
  - Interest by potential sources
  - Reserve capacity for this work
  - Capacity in excess of workload
  - Availability of skilled labor
  - Overhead structure
  - Stability of labor relationships
  - Customer knowledge
  - Product knowledge
  - Repair process knowledge
  - MRP-II-consistent management methods

The factors described here are the cumulative result of an extensive literature review, several internal LMI focus groups, and, in some cases, feedback during the trial applications described in Chapter 3. In the interest of conciseness, the descriptions of these factors will normally refer to the main effects. All of the factors have side effects of varying importance that would be burdensome to include here. (We did, however, include the side effects in the factor weights we used for building the additive utility model in Chapter 3.) Because the nature of the repair work itself is the least abstract, discussion begins with the factors in that class.

Nature of Repair Work Itself

Nine factors related to the nature of the repair work itself appear in previous depot maintenance studies and related literature. Below we describe each of these factors in turn.

WORKLOAD SIZE VS. SIZE OF MARKET

The first factor considers the relative size of the projected workload compared to the total market for similar work, including organic and private-sector repair workloads. The commercial sector can be attractive if it offers the government a large, preexisting infrastructure. This is the reason why the Air Force commercially supports the KC-10 aircraft. Placing one's requirements in the general commercial marketplace is sometimes referred to as "mainstreaming" one's requirements, that is, putting them into the commercial mainstream.

WORKLOAD SIZE COMPARED TO THE WORKLOAD AT SOURCES OF REPAIR

A related consideration is the size of the projected workload compared to the amount of similar work at contemplated sources of repair within a repair sector. If the workload is comparatively small, then no matter what specific source of repair it chooses, the government will be able to tap into a large, preexisting infrastructure. In contrast, if the workload is large compared to the total workload of a potential source of repair (or is likely to *be* the total workload), then the sources of repair will have less flexibility to respond to unexpected changes in demand, unless they deliberately maintain idle capacity. Further, capitalization costs may increase. Here again the KC-10 fleet provides a case in point. It is a small fraction of the DC-10/KC-10 fleet produced and serviced by Douglas Aircraft and its licensees.[30]

DEMAND PREDICTABILITY

The ability to predict demand is influenced by both statistical and state-of-the-world uncertainty. Statistical uncertainty is a fact of life for systems with stochastic failures. There is substantial evidence that even in peacetime the demand for complex, high-technology system repair has considerable statistical uncertainty and that the uncertainty gets worse in wartime.[31] State-of-the-world uncertainty, of course, is particularly challenging for wartime scenarios.[32] The unpredictability of demand resulting from both types of uncertainty places a premium on adaptability of the logistics chain,[33] including adaptability of the repair source. Adaptability of the repair source is what is at stake when the depot maintenance integrated management report describes, as one of the response capabilities not normally available from private firms, "the ability to increase output and change priorities within a wide compass of potential, but inherently unpredictable, needs."[34]

However, some workloads are more predictable than others. The implication is that the required adaptability of the repair sector also varies from workload to workload. Thus the choice of repair sector should take into account the anticipated demand predictability.

DESIGN STABILITY

An evolving design makes it more difficult to develop efficient repair processes; thus the repair sector that can better cope with this difficulty may be more attractive. The rate of change varies over the life cycle: it is generally higher during a system's early production phase. (Design instability is one reason that the original equipment manufacturer is often initially used as the initial source of repair.[35]) The stability of the design affects the relevance of a repair sector's ability to cope with design changes.

A second reason for potentially including design stability is that uncertainty of any kind makes it more difficult to write a contract.[36] The relevance is that, given a choice between an organic repair facility, an OEM repair facility, and a third-party repair facility, the third party could be least attractive if the design is unstable.[37]

Design changes do not always affect the repair process, however. For purposes of clarity we define the factor "design stability" to include only those changes that do affect the repair process.

TECHNOLOGY RENEWAL RATE

We will refer to the long-term rate at which one generation succeeds another as the technology renewal rate. For some technology areas, such as electronics, one generation of technology succeeds another as often as every 3 to 5 years.[38]

Insertion of updated technology has well-demonstrated benefits in terms of mission performance, reliability, maintainability, and cost reduction.[39] There is, logically, more opportunity where the technology renewal rate is higher. Further, the ability to capitalize on new technology depends in part on the source of repair (e.g., on the availability of an engineering staff). Differences in engineering capability between one repair sector and another, however, may not be important—results will depend on both the abilities of the repair sources within a repair sector and the renewal rate of the technologies specific to the workload under consideration. For these reasons we include the technology renewal rate as a potentially relevant characteristic of the workload itself.

UNIQUENESS OF TECHNOLOGY

As described earlier under the topic of extraordinary profits, fees, and earnings, one of the issues raised in the literature on transaction cost economic theory is asset specificity. In general, the greater the asset specificity, the more likely that a user will internalize production rather than contracting for it.[40] One reason, of course, is that there may not be an alternative—nobody else interested in the work. But even when there is an alternative, if the work is performed under contract then the asset specificity can lead to exploitative behavior such as charging high prices.[41] Firms (and governments) may decide to bring work in-house in

order to guard against the risk of exploitative behavior. The term "uniqueness of technology" is an attempt to capture one important facet of asset specificity in depot maintenance.

REPAIR PROCESS DEPENDENCE

A narrower facet of asset specificity is repair process dependence. A depot maintenance repair process may involve significant investment in skills, equipment, documentation, and facilities that are unique to one or a few workloads. Other things being equal, this will increase the cost of maintenance because of the initial nonrecurring investment to establish a capability. Repair process dependence, because it is an instance of asset specificity that would result in high costs to switch to an alternative supplier, can also lead to exploitative behavior.[42]

AVAILABILITY OF ENGINEERING DATA

Acquisition of the technical information needed for diagnosis and repair of equipment is of critical importance, because efficient repair of equipment obviously requires access to such information. There are logically two aspects to the engineering data question: whether the information exists at all, and if so whether it is proprietary. This factor addresses whether the engineering information exists.

ABSENCE OF PROPRIETARY DATA ISSUES

Even if the technical data exist, they will not necessarily be equally available to organic and commercial sources of repair if the original designer asserts proprietary (data rights) claims. This issue is of demonstrated practical importance to the repair sector selection decision—as the Air Force found when it privatized the Aerospace Guidance and Metrology Center at Newark Air Force Station.[43]

The problem is that data rights affect third-party commercial sources of repair more than government sources. The original designers of equipment are generally more willing to provide government depots access to their proprietary data than they are other commercial firms, because the government is unlikely to be a manufacturing competitor. Even in the absence of data rights claims, however, the OEM will likely gain a "first-mover" advantage over a third-party source of repair. The OEM possesses the engineering knowledge that permitted developing the data in the first place.

Nature of Relationship with Sources

The second category of factors includes those that reflect the relationship between the government and the potential sources of repair. Representative factors in this category include the type of contract (or equivalent administrative arrangement) between the parties; government policies on such considerations as lot size and

sources of repair parts; and the incentive structure. We have identified six such factors.

TYPE OF RELATIONSHIP

As noted earlier, one of the primary arguments for maintaining organic depot maintenance is to maintain the ability to "immediately increase output and change priorities within a wide compass of potential, but inherently unpredictable needs."

Two assumptions are built into this statement. The first is that there is a requirement to "immediately increase output and change priorities." This requirement stems from the large uncertainty associated with conflict—Clausewitz's "fog of war."[44] Hence the customer's requirement for flexibility—to be able to rapidly change priorities in order to respond to uncertain wartime demand—is probably uncontestable.

The second, unstated, assumption is that only organic sources can satisfy the requirement; and behind that assumption is a third: that the flexibility expected in a relationship with an organic depot makes it is easier to change requirements than with a commercial source. These assumptions find support in transaction cost theory and the literature on supply chain management, which show that it is generally harder and takes longer to provide for contingent performance through a contract mechanism than through a command mechanism.

The fact that it is generally harder and takes longer does not mean that it is always so. After all, as a result of information technology such as electronic data interchange, the cost per transaction and speed of transactions between trading partners are rapidly falling.[45] For these reasons, the relative ability to rapidly change requirements needs to be looked at on a case-by-case basis. Thus, it is a legitimate factor to be considered when deciding between repair sectors.

SCOPE OF RELATIONSHIP

If it is important to be able to levy contingent requirements on a source of repair, then it is obviously important for the source to have the flexibility to respond to changes in requirements. This is particularly the case where the repair volumes for individual components (most aircraft components, for example) are very low.

One determinant of flexibility is the scope of the relationship (illustrated, for instance, by the number of different types of components included). The broader the scope, the more the peaks and valleys from individual components' demand patterns will tend to level each other out when viewed in aggregate at a source of repair. If the individual components also use complementary processes and resources (similar skills, similar equipment, similar task sequences, etc.), then the source of repair can switch from repair of one component to another to respond to

a change in requirements.[46] Scope can be either vertical (many components from the same system) or horizontal (similar components from many systems).

Because government depots are generally large, integrated facilities but commercial repair sources may or may not be, this is a potentially relevant factor.

POLICY ON RELATED FUNCTIONS

The previous factor addressed the scope of the relationship in the context of how many components are repaired. Another more particular facet of that scope is the breadth of functional responsibility. The department, when contracting for depot repair, can hold the source of repair responsible for just repair or can broaden the responsibility to include other activities, such as sustaining engineering and materiel management.

Low-cost production of a heterogeneous workload (i.e., achieving economy of scope) depends, in part, on broadening functional responsibility.[47] As an example, the Coast Guard originally contracted with Lycoming/Textron for repair of LTS101 engine parts using a traditional repair-only contract. By converting this contract to power-by-the-hour (where a vendor is reimbursed based on the number of operating hours produced) and placing responsibility with Lycoming/Textron for engineering, rotable spares, and transportation, the Coast Guard decreased the shop visit rate by a factor of four and simultaneously reduced the annual support cost 50 percent.[48] The same considerations apply even if repair is performed organically. There is evidence, for instance, that where materiel management and engineering responsibility are separated the product improvement process essentially stops.[49]

The results described in the previous paragraph should not be a surprise. These are integrated logistics first principles—one gets better results when all of the important facets of a system are considered on an integrated basis. Thus, responsibility for functions related to repair is a factor that should be considered.

POLICY ON LOT SIZES

The repair lot size has a significant effect on flexibility to respond to changes in requirements.[50] Large lot sizes impair flexibility. In general, the operative Department of Defense policy has been and still is to batch unserviceable components prior to shipment to either a commercial or an organic source of repair, thus generating relatively large lot sizes.[51] However this is not necessarily a static policy and will not necessarily be uniformly applied across the commercial and organic sectors in the future. Thus it a candidate factor to be considered.

The time spent awaiting parts is a major contributor to total flow time at both commercial and organic repair facilities.[52] In part this is because department policy restricts how repair parts are obtained. Chenowith and Abell illustrate:

> The government purchases and manages many parts, commonly referred to as government furnished material (GFM), and is often the source of supply. When that occurs, a Military Standard Requisitioning and Issue Procedures (MILSTRIP) action takes place. In the event that the government discovers it cannot fulfill the request and additional supplies are not expected for some time, it gives the contractor permission to purchase the material on its own with Air Force funds.[53]

The coordination process for a contractor (or organic facility) to obtain permission to exit the MILSTRIP process takes time. There are even cases where repair parts purchased for one program cannot be used for another. When this happens the source of repair, contractor or organic, might have to requisition parts that it already has on hand.

Policies such as these, based on notions of accountability and *a priori* prioritization, have the significant disadvantage of extending flow times. It also stands to reason that the delivery uncertainty they introduce will increase variability in flow times. By contrast, a policy that provides the flexibility to obtain parts from the most responsive sources will reduce flow times and reduce variability. This thinking is, of course, part of the rationale for direct-vendor delivery programs in the commercial sphere and at the Defense Logistics Agency.

More important for our purposes, repair parts policies will have an effect when they are more flexible for one source of repair than for another. For this reason, the policy on repair parts is a factor to be considered when selecting the repair sector.

INCENTIVE STRUCTURE

Incentives and incentive structures figure in just about every report on depot maintenance. It should not be necessary to provide a substantial justification that incentives to reduce cost and improve productivity can make a difference. Here, our interest is on how the incentive *structure* the government puts in place affects the characteristics of repair sectors (as described earlier), rather than on the particulars of specific contract incentives. The incentive structure can be either intentional or, especially with organic sources, de facto.

Of particular importance is the difference between the incentive structure under competition versus a sole source. The monopolist's bargaining power can create distorted incentives—such as maximizing budgets and serving internal interests—rather than reducing costs, raising productivity, and serving the customer's

interest.[54] The potential for distorted incentives when the government is bound to a single commercial provider is generally recognized. Not as generally recognized is the fact that organic providers can also hold a monopoly position.[55]

Even where formal competition is absent, it is possible to get some of the effects of competition if a sole-source provider can be disciplined by the potential entry of a competitor.[56] Thus, from the standpoint of incentive structure, creating or retaining an organic capability may have merit if the only alternative is a commercial sole source. Obviously, the reverse argument also applies: using a commercial source may have merit if the only alternative is a government source.

Nature of Sources

The third category of factors that influence the characteristics of the sources of repair is directly related to the nature of the commercial and organic sources of repair themselves. We identified 12 factors in this category.

AVAILABILITY OF MORE THAN ONE SOURCE

The reasons for considering the availability of more than one source are the same as those presented above with regard to incentive structure. The bargaining power a sole source wields can create distorted incentives—such as maximizing budgets and serving internal interests—rather than reducing costs, raising productivity, and serving the customer's interest. As we discussed previously, both commercial and organic sources can be in a monopoly position. Not surprisingly, it was clear from our interviews with field personnel that the availability of more than one source was of primary importance in repair sector selection decisions.

AVAILABILITY OF SOURCES WITH COMPLEMENTARY WORKLOAD

Complementary workload is workload that requires equipment, training, and skills similar to the workload under consideration. The reasons for including this factor are in part the same as those presented earlier with regard to the scope of the relationship. If repair sources have other, complementary workload, they are in a better position to accommodate the peaks and valleys of individual component demand patterns.

In addition, and potentially more importantly, sources with complementary workload are able to spread the fixed costs of equipment and training over a wider workload base. In the absence of complementary workload, the customer user bears the entire cost.

INTEREST BY POTENTIAL SOURCES

Interest by potential sources is important from two standpoints. First, if there are no interested commercial sources (as can be the case with obsolete technologies),

then the government must either do the repair itself or insert new technology through redesign.

Second, a single interested source can exercise the monopoly bargaining power described above. Having multiple interested sources hedges against this possibility.

RESERVE CAPACITY FOR THIS WORK

Capacity is the amount of workload that a facility can effectively turn out while producing the product mix that the facility is designed to accommodate.[57] If a source of repair is already producing at capacity, then it will necessarily have to make a capital investment to provide additional capacity. Other things being equal, a repair sector comprising sources of repair that do not have to make this investment will produce at lower cost, since its sources of repair would not have to amortize the investment.

CAPACITY IN EXCESS OF WORKLOAD

The previous factor addressed the availability of reserve capacity. However, capacity is a two-edged sword. Unutilized capacity increases overhead costs—a continuing problem for both the organic depots and their commercial counterparts.[58] Because there are two different capacity-related considerations, which act in opposing ways, we have provided a second factor, capacity in excess of workload.

AVAILABILITY OF SKILLED LABOR

Availability of the right personnel quantities and skills is a well recognized and fairly obvious requirement for maintenance activities. It is of sufficient importance for new systems that personnel training is a logistics element in its own right. Thus, the degree to which skilled labor is already available is a legitimate factor when comparing one source of repair to another.

OVERHEAD STRUCTURE

Potential sources of repair can differ significantly in their overhead structures and, as a result, their indirect costs. For example, original equipment manufacturers carry large engineering staffs. As a result, if the engineering staffs are in the same overhead pool as that applied to maintenance, then they will have higher rates than contractors whose overhead pools are more narrowly focused on maintenance. For this reason, overhead structure is included as a relevant characteristic of the repair sectors.

At least two points should be clarified. First, organic depots in recent years have experienced significant overhead rate increases, but the reasons have more to do

with excess capacity, already provided for above, than with overhead structure in the sense meant here.[59] Second, it would be incorrect to conclude that OEMs always have high overhead rates. It is not unusual for OEMs to create independent service companies specifically designed to have low overhead rates.

STABILITY OF LABOR RELATIONSHIPS

As discussed earlier in this chapter, an important reason why DoD managers tend to prefer organic sources is the perceived risks in using commercial sources. One mentioned often (both informally and in formal reports) is the possibility that strikes might interfere with production. Because of this concern, we include stability of labor relations as a factor.[60]

CUSTOMER KNOWLEDGE

One of the innovative practices characteristic of successful private-sector firms is a continual effort to know the customer better than the competition does.[61] By customer knowledge we mean the detailed understanding needed to capture customer requirements and translate them into performance meaningful to the customer. For maintenance, the detailed understanding that is customer knowledge takes the form of both customer production requirements and engineering knowledge (such as failure modes and effects) of the customer's equipment.

Despite expectations to the contrary, organic depots may not necessarily be in a privileged position to have such customer knowledge.[62] Because of the structural relationships between depot production and the DoD materiel management systems, the customer of the depot is the item manager more so than the field user. Among the longstanding results are significant gaps between what is in work in DoD depots and what customers actually need.[63]

PRODUCT KNOWLEDGE

The specialized knowledge of the product itself, like knowledge of the process, is a qualifying factor that tends to favor the incumbent source of repair. Product knowledge includes such information as product history and histories of sister products; details of the tradeoffs that were made during product design; details of manufacturing processes; failure history and failure modes; as well as historical, present, and planned logistical support methods.

REPAIR PROCESS KNOWLEDGE

The specialized knowledge of repair processes needed to accomplish maintenance is a natural barrier to entry into the market for weapon system component repair. Thus, in choosing a repair sector, the availability of this process knowledge is a relevant factor. Generally, of course, it is a factor that would tend to favor incumbents, whether organic or contract.

In recent years, as part of its effort to modernize automation, the DoD depot maintenance community has defined a set of preferred management methods in an improved functional baseline.[64] These preferred methods mirror improvements in the commercial manufacturing world that have permitted successful competition in a market-driven environment. The short-hand term for the improved methods is manufacturing resources planning (MRP-II).[65] The fairly lengthy list of improved management methods that makes up MRP-II includes

◆ multipurpose structured bills of material with individual item tracking capability;

◆ automatic consideration of engineering change notices;

◆ automatic, time-phased, planned shop and material orders;

◆ incorporation of priority factors during scheduling;

◆ item-level planning, tracking, history, and rescheduling;

◆ continual recalculation of resource requirements based on planning schedules, detailed bills of material, and activity;

◆ automatic reprioritization based on changes in customer requirements (deexpediting); and

◆ linkage of capacity requirements planning to time-phased resource scheduling.

The evidence is compelling that absence of such improved methods (particularly the inability to reprioritize based on changes in customer requirements) results in long repair cycle times, large in-process inventories, and misapplied resources, in both the organic depot maintenance sector and in DoD's supporting contractors.[66]

Because of the success of MRP-II methods in manufacturing; demonstrated benefits of MRP-II-like methods in repair (e.g., remanufacturing); and less than satisfactory results in the absence of these methods, availability of MRP-II methods is a legitimate factor.

SUMMARY OF ELEMENTS IN THE NEW DECISION MODEL

This chapter has described a conceptual decision model with three levels. Table 2-1 summarizes the elements at each level.

Table 2-1. Elements of Decision Model at Each Level

Customer needs	Characteristics of sources of repair	Factors that determine the characteristics
Ability to meet basic demand Agility and responsiveness in the face of changing demand Quality product and service Low total cost Continuous improvement of both product and service	Adequate capability and capacity Scope and scale economy Overhead costs Non-value-added work Extraordinary profits, fees, and earnings Responsiveness to changing needs - Reprioritization capability - Surge capability - Task flexibility - Customer linkage - Administrative ease Incentive to improve Work stoppage protection Pipeline size (quantity and time) - Order and ship (admin.) - Repair cycle at source of repair (SOR) - Material movement (user to SOR and return) Output quality - Of product - Of service	Nature of repair work itself - Workload size vs. size of market - Workload size compared to the workload at sources of repair - Demand predictability - Design stability - Technology lifetime - Uniqueness of technology - Repair process dependence - Availability of engineering data - Absence of proprietary data issues Nature of relationship with sources - Type of relationship (flexible vs. inflexible) - Scope of relationship - Policy on related functions - Policy on lot sizes - Policy on repair parts - Incentive structure Nature of sources - Availability of more than one source - Availability of sources with complementary workload - Interest by potential sources - Reserve capacity for this work - Capacity in excess of workload - Availability of skilled labor - Overhead structure - Stable labor relationships - Customer knowledge - Product knowledge - Process knowledge - MRP-II-consistent management methods

OPERATIONALIZING THE MODEL

The basic logic of the decision model, as illustrated earlier in Figure 1-1, is that the extent to which each repair sector can satisfy customers depends on the characteristics of the repair sectors. Those characteristics depend, in turn, on the nature of the repair work, the nature of the relationship the government has with its repair sources, and certain inherent factors related to the sources themselves, whether public or private.

We operationalize this model in a simple mathematical form in Appendix A. Our approach depends on establishing evaluation criteria, weighting the criteria, and evaluating RSS alternatives against them to determine which alternative scores the highest. Appendix B describes a technique for interpreting the scores in terms of relative risk.

The mathematical form described in Appendix A and the method for interpreting results described in Appendix B are consistent with those used in DoD procurement source-selection procedures. For that matter, so is the whole concept of establishing criteria, weighting the criteria, and evaluating alternatives.[67] A major reason for taking this approach is that if the basic procedure is acceptable for procurements generally, then it logically also ought to be acceptable for a close analogue, the repair sector selection decision.

LIMITATIONS OF THE MODEL

The evaluation approach described in this report focuses on the requirements of the depot maintenance customer and the ability of a sector to satisfy them. In taking this approach, we have excluded a number of potentially important considerations:

◆ Equity considerations (for example, effects on the government or contract workforce of shifting workload from one to the other).

◆ Interaction with overall program acquisition strategy. For example, if a program is, for other reasons, considering interim contract support, that decision and the RSS decision probably should be taken together.

◆ Affordability within budget. It is possible that the preferred choice of sector would simply not be affordable within the available budget if it requires large up-front investments.

◆ Political considerations.

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Additionally, because the approach is inherently incremental, workload-by-workload, it does not address issues relating to long-term planning regarding depot maintenance.

End Notes for Chapter 2

[1] John Keenan et al., *Issues Concerning Public and Private Provision of Depot Maintenance*, Center for Naval Analysis CRM 94-65, April 1994, p. 11.

[2] Cf. *Gulf War Air Power Survey*, Volume III, "Logistics and Support," p. 342;

Joint Uniform Lessons Learned System Long Reports from the U.S. Army Materiel Command Desert Shield/Desert Storm lessons learned databank show both an in-theater maintenance surge (e.g., M-1 rollover) and a manufacturing surge;

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Chapter 3
The Repair Sector Selection Decision Process

To reach public versus private repair sector selection decisions that are consistently in the best interest of the department requires a process that incorporates

- ◆ a decision model—i.e., a representation of the various elements of the RSS decision and their interrelationships—that captures most of what is important to the decision;

- ◆ a method for bringing to bear reasonably complete and unbiased data on both the public and private sectors;

- ◆ a procedure for interpreting the output of the decision model; and

- ◆ a provision for executive-level holistic evaluation.

This last provision recognizes that a model is an aid to executive judgment, not a substitute for it. We include provision for holistic evaluation to guard against attributing more credence than appropriate to the precise-appearing scores that a decision model can yield. Although the RSS decision model incorporates most of the relevant decision elements in a reasonable way, there will always be important externalities. An explicit model such as described in Chapter 2 is a simplification of a deeper and more complete tacit understanding.[1] For instance, although we identified some of the potential externalities at the conclusion of Chapter 2, others may be present as well. Further, since the input data are provided by people and reflect their individual judgments, a common-sense test of overall reasonableness is warranted in any event.

It was clear from previous work related to the RSS decision and from the interviews we conducted that the existing processes do not satisfy the four needs listed above, particularly the first two. The problems with the existing decision models (decision tree, life-cycle cost, CORE) were described in Chapter 2. Serious problems also exist in the way the inherently judgmental input data are obtained. As will be discussed more completely below, such judgments are subject to numerous sources of intentional and unintentional bias. We do not see provisions in the present processes to guard against such bias. For instance, by failing to include private-sector personnel in the existing methods it is highly likely (and corroborated by this study, in Chapter 4) that the government's understanding of the private sector is biased, simply because it is incomplete. Similarly, relying on government personnel who may have a stake in the outcome will tend to produce bias, no matter how good their intentions.

To address problems with the existing decision approaches, we designed a revised four-step process to correspond to the four necessary components (Figure 1-2). Chapter 2 described the first component, the proposed new RSS decision model. This chapter describes the second and third components. Discussion begins with step 2, obtaining input data. It then continues with the process for interpreting results. We do not describe development of a briefing for presentation to the program manager or other person designated to make the RSS decision, which is assumed to follow normal administrative practice. Neither do we describe the executive level, holistic evaluation itself, which is assumed to be integrative and unstructured.

ELICITING INPUT DATA

Three problems need to be solved in eliciting the input information. First, the information needed for a rational decision is initially dispersed among many individuals and probably disparate organizations, rather than integrated. Hence, there has to be some means for assembling and integrating the information. The second problem is guarding against bias, and the third is providing for reasonable consistency from one RSS evaluation to another.

Joint Evaluation

To address these three problems, we designed a data elicitation method as a companion to the new decision model. The method relies on eliciting the data in an integrated product/process team setting. The IPT members comprise system program office personnel (both technical and contract management), DoD depot representatives, and industry representatives.

The IPT-based method involves assembling personnel with knowledge of the issues important to the repair sector selection decisions, as described above; providing an introductory familiarization briefing on the purpose of the evaluation; and having the members of the IPT collectively determine the scores for each repair sector on each of the factors under consideration.

Addressing Bias

The substantial literature on eliciting judgments indicates that judgments are subject to numerous sources of intentional and unintentional bias.[2] Intentional bias is usually attributed to motivational issues, and unintentional bias to cognitive limitations.

Our review of the relevant literature indicates that potentially relevant intentional/motivational biases include

◆ outright selfishness and guile;

◆ wishful thinking (responding based on hoped-for results);

◆ impression management ("What would my organization think of my answer?");

◆ misinterpretation (tacitly assuming a meaning based on experience with similar sounding terms); and

◆ misrepresentation (making an invalid assumption about a probability distribution—such as ignoring low-likelihood events or considering only a few possible outcomes—when encoding a response).

Similarly, relevant cognitive biases include

◆ failure to take into account base rates (ignoring the lessons of experience and history);

◆ anchoring without adequate adjustment (for example, attaching too much importance to a particular, generally recent, event with which a person is familiar);

◆ inconsistency (forgetting an assumption made earlier and contradicting it);

◆ availability (recalling familiar, concrete, or recent events and overestimating the frequency of similar events);

◆ underestimation of uncertainty (resulting in failure to account for the actual amount of uncertainty in answers given); and

◆ failure to seek evidence to the contrary.

To provide some protection against these sources of bias, we incorporated both "direct" elicitation and focus group techniques in the elicitation method. Direct elicitation was implemented in the form of a structured, workbook-based questionnaire. The IPT naturally constitutes a focus group and in so doing gains the advantage of focus group pooled judgments.[3] Table 3-1 details how we sought to mitigate each of the bias problems.

Table 3-1. Sources of Bias and Mitigation Methods

Potential source of bias	Method used to counter bias
Selfishness and guile	Included experts from both government and industry repair sectors to provide checks and balances on each other
Wishful thinking	Included experts from both government and industry repair sectors
Impression management	Included experts from both government and industry repair sectors
Misinterpretation	Used common terminology, and pretested the terminology to guard against misinterpretation
	Provided an evaluation workbook with defined terms
	Explained terms as needed during the elicitation
Misrepresentation	Provided background information on expected distributions for each factor
Failure to take base rates into account	Provided background information on expected distributions for each factor
Anchoring without adequate adjustment	Group performed the assessments, rather than individuals
Inconsistency	Grouped and limited the number of questions
	Provided a workbook to each evaluator with space to make notes
	Provided standardized rating scales with defined anchors
Availability	Included experts from multiple functional areas (e.g., depot maintenance, program management, contract management; from both government and industry)
Underestimation of uncertainty	Permitted range rather than point responses
	Did not insist on consensus answers; difficulty in reaching consensus was taken as an indicator of uncertainty and a need for sensitivity analysis
Failure to seek evidence to the contrary	Included experts from both government and industry repair sectors

Consistency Among Evaluation Sessions

To encourage consistency of scoring between one evaluation session and another, we developed a set of rating scales and published them in an evaluation workbook used during the trial evaluations. An example rating scale is illustrated in Figure 3-1; the workbook is in Appendix C.

Figure 3-1. Example Rating Scale

Relative size (amount) compared to marketplace

1	3	5	7	9

| This workload is the total market. No other similar workload exists anywhere. | Total market includes other similar work that may be partially commercial. This workload is the driver—greater than 50%. | Total market includes other similar work; approximately equal proportions of military and commercial. | | This work is in the commercial mainstream. Absence or presence of this workload would have no signifcant effect on the market. |

The rating scale comprises three parts. The first is a statement of the dimension being evaluated. The second is a line from worst assessment to best assessment with five marked points on the line (an interval scale). The third part is a set of defined anchors for particular points on the line. All of the rating scales have at least three defined anchors, one each for the worst (1), typical (5), and best (9) evaluations. Some, such as the scale illustrated in Figure 3-1, also have the (3) and/or (7) points defined. We did not attempt to provide a definition for a point where the definition would have been more forced than useful, such as for (7) in Figure 3-1. The scale illustrated is a version of the classical Likert method, with both numerical and verbal labels for the categories of answers.[4] The reason for including both numerical and verbal labels is that people prefer to communicate uncertainty verbally but receive it numerically, while the accuracy of the two different response modes is essentially the same.[5]

INTERPRETING RESULTS

When the scores comparing two sectors are input into the mathematical model (described in Appendix A), the results look like Table 3-2.

Such a display establishes that repair Sector B scored overall higher than repair Sector A (0.321 versus 0.312). It also indicates what differences at the customer-need level contributed to the higher score. For example, the customer need for "quality product and service" differs by 0.019, whereas both sectors have nearly the same score for "surge."

Table 3-2. Example Results from Mathematical Model

Factor	Subfactor		Sector A	Sector B
Overall comparison	....		0.312	0.321
	Meet basic demand		0.337	0.340
	Agility/responsiveness:	Reprioritize	0.485	0.509
		Surge	0.406	0.405
		Adapt	0.236	0.236
	Quality product and service		0.357	0.376
	Low total cost:	Of maintenance, per se	0.352	0.377
		Of administration	0.253	0.260
		Of capitalization	0.190	0.193
	Continuous improvement of quality and service		0.192	0.197

What such a display does not do is provide insight into the significance of overall scores like 0.312 and 0.321. Without additional information, we would not know how meaningful the difference is, nor would we know whether either sector poses a low risk to satisfaction of customer needs, an average risk, or a high risk.

An approach to establishing the meaning of these scores is to recognize that if the results of many such analyses were available, then the pattern of those results would form a backdrop against which the current analysis (Table 3-2) could be viewed. However, we are describing a new methodology and the results of many such analyses are not available. (Further, even if the methodology had been in place for some time, prior results would not necessarily be available.)

Nonetheless, one can artificially create a backdrop of "results" by simulating the performance of a large number of analyses. The distribution of results in Figure 3-2 was generated by simulating RSS evaluations many times while, in each instance, randomly choosing input factors from preestablished "reasonable" statistical distributions for each of the evaluation factors. (Appendix B documents the assumed distributions for the evaluation factors.) Based on the central limit theorem, one would expect an approximately normal distribution of the resulting evaluations, even if distributions of individual evaluation factors are not normal and not identically distributed.[6] The approximately normal distribution is readily apparent in Figure 3-2.

Figure 3-2. Simulated Distribution of Many Evaluations
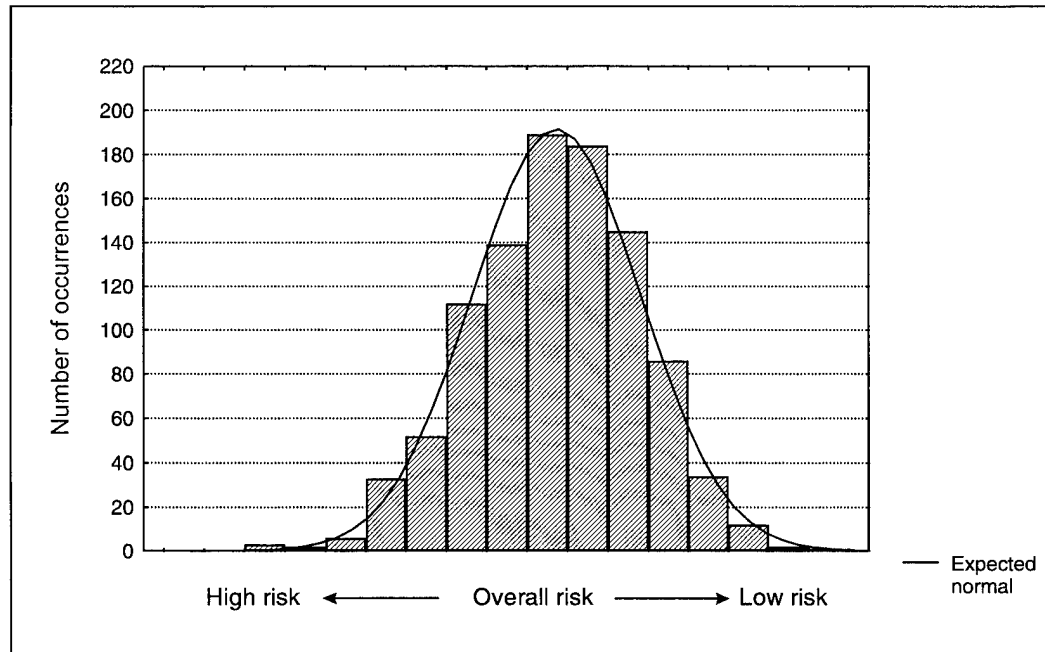
We made use of this simulated distribution to define relative risk in terms of the distribution's calculated mean and standard deviation. The general idea is illustrated in Figure 3-3.

Figure 3-3. Example Assessment of Risk
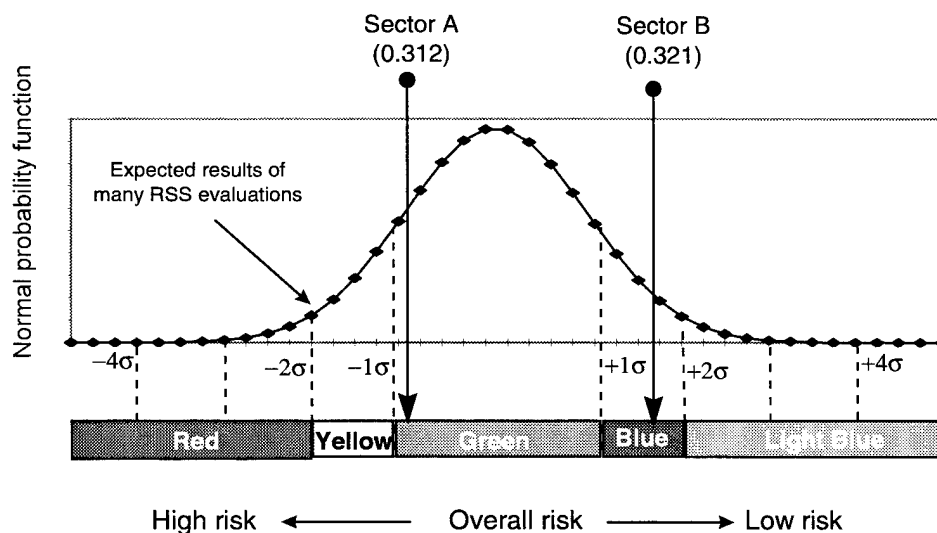
In Figure 3-3, the area between -1σ (standard deviation) and $+1\sigma$ is arbitrarily colored green to indicate the range of acceptable risk. Together, this and the other areas on this figure mean the following:

Range	Color	Meaning
-4σ to -2σ	Red	Unacceptable risk
-2σ to -1σ	Yellow	Questionable risk
-1σ to $+1\sigma$	Green	Acceptable risk
$+1\sigma$ to $+2\sigma$	Blue	Low risk
$+2\sigma$ to $+4\sigma$	Light blue	Very low risk

With this backdrop, if the Sector A score of 0.312 and the Sector B score of 0.321 plotted in the locations indicated, then one could conclude that the risk of Sector A was acceptable (but close to the questionable region), while Sector B had low risk. (Similar comparisons can be performed on each of the individual customer needs.)

The color-rating process just described is consistent with that used in DoD procurement source-selection procedures. For that matter, so is the method of establishing criteria, weighting the criteria, and evaluating alternatives against criteria.[7] However, in source selections the dividing points between acceptable and unacceptable risk are entirely judgmental. Thus, one of the things we have added to the usual practice is a statistically-based rule for establishing those breakpoints. Even more important, though, is that if the basic procedure is acceptable for procurements generally, then it logically also ought to be acceptable for what amounts to a close companion—the repair sector selection decision.

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Chapter 4
Testing the New Model and Process—
Results and Recommendations

Repair sector decisions are by nature controversial, and there is a history of previous approaches to the repair sector decision that were partially successful, were only partially implemented, or that simply were not adequate to the task.[1] Thus it is important to demonstrate that the model described in Chapter 2 and the decision process described in Chapter 3 work in practice.

We tested the new model and process on three different V-22 aircraft workloads. This chapter describes the conduct of and results of the trial applications.

PROCESS FOR CONDUCTING TRIAL APPLICATIONS

We implemented the three-tier evaluation model described in Chapter 2 in a software product called QFD/Capture and in an Excel spreadsheet. QFD/Capture, because of its graphical nature, was a better tool for establishing the relative importance of repair customer needs, assigning the weights that link customer needs to the characteristics of choices, and assigning the weights linking characteristics of choices to determining factors. The Excel spreadsheet was used to do calculations because Excel offered certain calculation capabilities not available in QFD/Capture.

The importance of each customer need was initially assigned by LMI analysts and then checked for reasonableness during field interviews. We also developed a preliminary set of weights linking customer needs to the characteristics of choices and characteristics of choices to determining factors. We developed the weights using a focus group comprising LMI staff members knowledgeable in depot maintenance, acquisition, sustaining engineering, inventory management, and modern manufacturing methods. Every effort was made to establish reasonable weights, and the final weights include feedback from trial evaluations. However, the weights largely remain the product of this one focus group. Future corroboration by another focus group or by other means is appropriate.

Using the evaluation model described in Chapter 2 (with LMI-developed weights) and the decision process described in Chapter 3, the V-22 system program office (SPO) conducted trial evaluations on the T-406 engine, the V-22 forward-looking infrared scanner, and the Cockpit Control Feel and Drive actuator. These three subsystems were legitimate repair sector decision candidates that the V-22 SPO was actively evaluating. They are also representative of the span of components

that might be subject to evaluation, since one of them embodies propulsion technology, one is an avionics subsystem, and one is electromechanical.

For each of the components, evaluators assessed alternative repair sectors using the factors described in Chapter 2. The overall process is illustrated in Figure 4-1. Attendees received evaluation workbooks one or more days before the evaluation session so that they could do preparatory research. The sessions themselves began with an opportunity approximately 1 hour in length for government and contractor representatives to give an overview briefing (this opportunity was not always used) or make introductory remarks. The evaluations themselves took about 4 hours. The times shown in the "Analysis" column in Figure 4-1 are representative of the effort required for one analyst to perform these tasks.

Figure 4-1. Process for Conducting Trial Applications
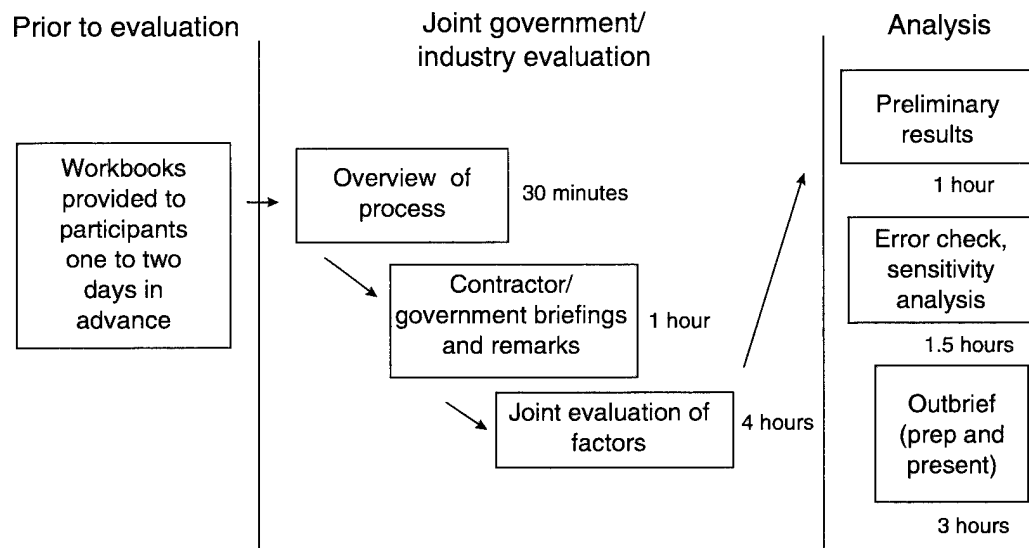
The four evaluations that took place are summarized in Table 4-1. LMI staff members who had contributed to the methodology acted as facilitators for the evaluation sessions but did not contribute to the assignment of scores. The government and contractor representatives worked as an integrated process team to reach consensus on both the organic and contract alternative scores. In the few cases where it became apparent that the consensus was becoming forced, our facilitators kept track of the range of scores and used the ranges later for sensitivity analysis. After the evaluators scored the repair sectors on each factor, we compiled the results, did the sensitivity analysis, and conducted the outbriefing.

Table 4-1. Trial Evaluations

Session number	Component evaluated	Panel membership
I	T-406 engine	System program office and cognizant maintenance depot
II	T-406 engine	System program office, cognizant maintenance depot, and engine OEM
III	FLIR	System program office, cognizant maintenance depot, and FLIR OEM
IV	CCFD	System program office, cognizant maintenance depot, and airframe OEM (did not include CCFD vendor)

TRIAL APPLICATION RESULTS

We expected that a sequence of trials would be required to refine the evaluation scales and process, and this proved to be the case. The major problems we encountered are summarized in Table 4-2. The first problem listed had to do with the model itself, and the next four involved how the evaluation was conducted. The final problem, as indicated, may or may not actually be a problem and will require further trial evaluations to better characterize. We discuss each of these problems below.

New Factors

Evaluators sometimes were unable to find a factor that would let them express a difference between the repair sectors in an area that they thought was important. We identified the missing factors and, after additional research confirmed their relevance, added them. Examples are reserve capacity for the proposed workload, capacity in excess of workload, customer knowledge; and policy on repair parts.

Scales with Vague Anchors or Confusing Terminology

In some cases the evaluators agreed with the need for the factor they were evaluating but had difficulty agreeing on its meaning; it would take extensive conversation to define it, and later they would have difficulty remembering the definition. This confusion could lead to possible inconsistency bias. The key to resolving this problem was better-defined anchors. For example, Figure 4-2 shows the initial vague set of anchors for the factor "demand predictability" and the final, more concrete anchors. We proceeded to refine the anchors throughout the trials.

Table 4-2. Problems Noted During Trial Evaluations

Problem	Approach to resolution	Results
Apparently relevant factors not included.	Added factors.	Problem appeared to be resolved.
Scales for some factors had vague anchors or confusing terminology.	Redefined anchors and terminology.	Problem appeared to be resolved.
Evaluators did not understand the relevance of some of the factors.	For each factor in the workbook, provided a graphical display indicating which repair-sector characteristics the factor affected.	Problem appeared to be resolved.
Evaluators did not have sufficient knowledge of organic and contractor capabilities and/or proposed business arrangements to fairly evaluate both organic and contractor alternatives.	Included contractor representatives in Sessions II, III, and IV. (However, this problem reoccurred in Session III, when the government evaluator did not fully understand the organic capabilities.)	The process as designed will not adequately resolve this problem, since it does not control who will be selected as evaluators.
Evaluators had a stake in outcome, leading to apparent (though possibly unintended) motivational bias.	Included experts from both government and industry repair sectors.	The process as designed will not adequately resolve this problem, since it does not control who will be selected as evaluators.
Preponderance of low-risk evaluations appeared in trial evaluations.	Not clear whether this reflects reality (i.e., the repair sectors were actually low risk for the subsystems evaluated) or is an artifact of the risk analysis procedure. Additional evaluations are needed to better characterize.	Not fully resolved, because the cause is not certain.

Relevance of Factors Not Clear

Evaluators sometimes did not understand why they were evaluating a particular factor and what repair sector characteristics a factor affected. We addressed this problem by revising the workbook to include a display like that shown in Figure 4-3, for the factor "reserve capacity." The filled dots in this display indicate that the factor affects adequate capability and capacity, reprioritization capability, and surge capability. The fact that the dots are completely filled (as opposed to three-quarters filled, half filled, quarter filled, or open) indicates that the relationship of reserve capacity to the characteristics is very important.

Figure 4-2. Revised Factor Scale Anchors

III-3. Demand predictability				
	1	3	5	7	9
Initial anchors	Poor predictability		Average predictability		Good predictability
Revised anchors	Forecasting of little or no avail. Peaks and valleys of workload are so extreme that best plan is to react.		Forecasting of some use. However, workload will vary from calendar quarter to calendar quarter.	Not deterministic, has peaks and valleys, but amount of workload consistent from one calendar quarter to another.	Deterministic. No surprises. Forecast workload and actual workload are identical (e.g., time change items)

Figure 4-3. Workbook Display Establishing Relevance of Factor

Evaluation Factor: V-4.
Reserve capacity at a potential source of repair for this work.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
●						●	●	
Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	

Insufficient Knowledge of Capabilities or Proposed Business Arrangements

On completion of Session I, which did not include evaluators from industry, we suspected that a number of biases could have been present.[2] Because of the possibility of a biased result, we arranged to repeat the evaluation with evaluators from the engine OEM present (Session II). The differences between the two sessions were striking.

In Session I, as an example, government evaluators were convinced that the engine OEM had labor difficulties that would result in a strike within weeks of the evaluation. Discussion during Session II showed this belief to be unfounded. This erroneous information, however, influenced the results, since labor relations is an evaluation factor. The problem, of course, is that near-term labor issues surrounding one contractor are largely irrelevant in the context of a long-term repair sector decision. This is a clear case of availability bias. Similarly, the "power-by-the-hour" business arrangement that had been proposed by the engine OEM was not clearly understood by some of the government representatives, and that lack of understanding affected most of the factors under the category of nature of relationship with sources (probable misinterpretation bias). It also turned out that the engine OEM did not have a complete picture of organic capabilities.

The difference that contractor representation made is quite evident in the overall evaluation scores. Figure 4-4 contrasts the overall results of Sessions I and II. Both organic and contract scores improved; the contract score improved dramatically, resulting in a reversal of the source preference from organic to contractor.

Figure 4-4. Comparing Results of Sessions I and II
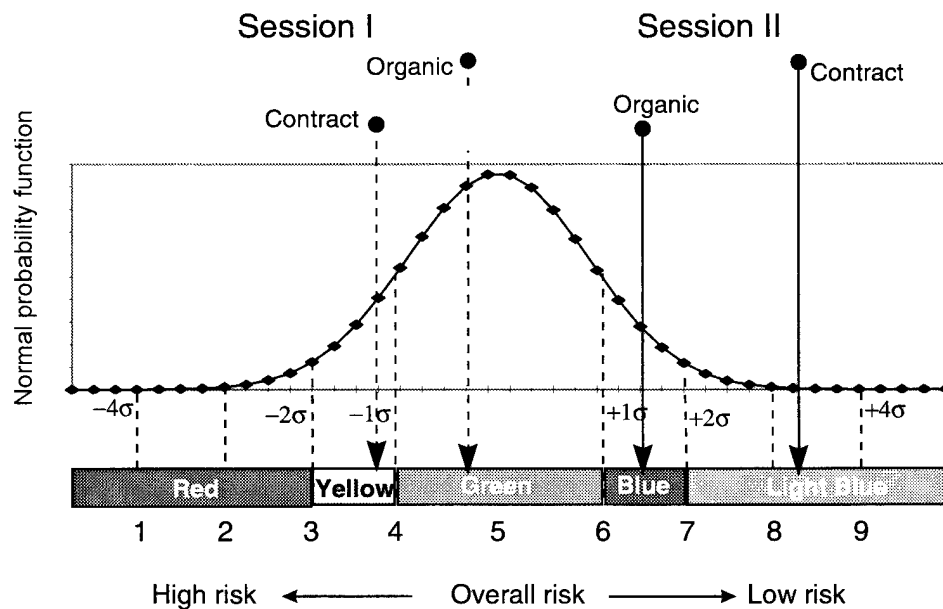
It should be emphasized that in Session II the combined evaluation panel (SPO personnel, organic depot personnel, and contractor personnel) generated, for the most part, consensus evaluations of both the organic and contractor alternatives as an integrated team. That is, it was not a case of the contractor scoring the contractor alternative and the government scoring the organic alternative. (As noted earlier, in the few instances where it appeared that consensus would be forced, the LMI facilitators kept track of the range of scores and used the ranges later in sensitivity analysis.)

Session III had almost the opposite of the problem encountered in Session I, because the individual available to evaluate for the government did not have a solid grasp of organic capabilities or issues. (We did not have the opportunity to repeat the FLIR evaluation.)

EVALUATORS WITH STAKE IN OUTCOME

Another way to read the difference between Sessions I and II is that government evaluators in Session I, who were from a government depot, had a stake in the outcome and thus a conflict of interests. In the trial applications of the decision process, we addressed this potential problem by bringing representatives of both industry and government depots to the table as an IPT. As will be discussed later in this chapter, we do not believe this approach is an adequate safeguard against the motivational biases that can arise from conflicted evaluators.

PREPONDERANCE OF LOW-RISK EVALUATIONS

In Figure 4-4, above, both the government and contractor alternatives in Session II were regarded as having low risk. In this particular case our holistic sense of the alternative repair sectors suggests such a result is not unrealistic. However, this same pattern, assessment of low risk for both alternatives, prevailed in Sessions III and IV as well. We are not sure whether the results are an artifact of the limited sample we examined (i.e., they were simply all low risk) or of the evaluation procedure itself. Only additional evaluations can shed light on this question.

ASSESSING THE REPAIR SECTOR DECISION MODEL AND DECISION PROCESS

In this section we present an overall evaluation of both the repair sector decision model and the repair sector decision process, beginning with discussion of the model.

Usefulness of the Model

In Chapter 2, we identified 27 potential evaluation factors in the three categories of nature of repair work itself, nature of relationship with sources, and nature of the sources of repair. There was support for the model elements at all three levels, and the evaluation sessions indicated the overall conceptual model is reasonable; but it still remained to be determined which of the 27 evaluation factors should be retained. Reasonable criteria for retaining a factor should include the following, for the reasons indicated:

◆ The factor is important to satisfying customer needs. Since it requires effort to obtain data on any of the factors, a factor that is not important should be discarded in the interest of a parsimonious model.

◆ The factor evaluation is sensitive to the choice of repair sector being evaluated. Even if a factor is important to a customer, if the choice of repair sector does not improve or impair ability to satisfy the customer's needs then the factor is not relevant to the repair sector decision.

◆ The construct behind the factor is understood by the evaluators. If it is not, the factor is not meaningfully contributing to the decision and may instead be introducing random biases.

◆ Evaluators are able to obtain sufficient information on the factor to evaluate it.

We concluded that 22 of the original 27 factors met all of the criteria. Appendix D summarizes the evaluation results for each of the original 27 factors. The five factors that should probably be eliminated and the main reasons for eliminating them are summarized in Table 4-3.

Table 4-3. Factors That Are Candidates for Elimination

Factor	Rationale for eliminating
Workload size versus size of market	Relative size of workload compared to marketplace for similar work is not important to choice of repair sector. The more relevant factor was size of workload compared to each repair sector.
Technology renewal rate	Not helpful in choosing between repair sectors, since preference for one sector or the other does not depend on underlying technology renewal rate.
Uniqueness of technology	Not helpful in choosing between repair sectors, since preference for a sector does not depend on uniqueness of technology.
Availability of engineering	Not relevant to the choice of repair sector. The relevant factor is absence of proprietary data.
Overhead structure	Evaluators had difficulty evaluating this factor, especially when attempting to generalize over all possible commercial sources of repair or over all possible organic sources of repair.

The retained factors, along with their ordinal ranks (i.e., rank based on computed importance) prior to eliminating any factors, are listed in Table 4-4.

Perhaps it is not surprising that the factors most important to getting a good deal for the repair services customer were incentive structure and customer knowledge, followed closely by type of relationship and availability of alternative sources.

At least two of the 22 retained factors, however—reserve capacity for this work and capacity in excess of workload—will require work beyond that accomplished in this study. We did not completely resolve problems associated with assessing

capacity; evaluators had difficulty with the capacity construct in each evaluation session.

Table 4-4. Retained Evaluation Factors

Category	Decision factor and rank
Nature of the repair work	• Relative size of work compared to work size of source of repair (13) • Demand predictability (24) • Design stability (23) • Repair process dependence (17) • Absence of proprietary data issues (18)
Nature of relationship with sources	• Type of relationship (flexible vs. inflexible) (3) • Scope of relationship (15) • Policy on related functions (9) • Policy on lot sizes (14) • Policy on repair parts (7) • Incentive structure (1)
Nature of sources	• Availability of more than one source (4) • Availability of sources with complementary workload (12) • Interest by potential sources (8) • Reserve capacity for this work (21) • Capacity in excess of workload (19) • Availability of skilled labor (10) • Stability of labor relationships (27) • Customer knowledge (2) • Product knowledge (11) • Repair process knowledge (6) • MRP-II consistent management methods (5)

Evaluation Process

The process poses two potential issues. The first is how much effort the process takes. The second is what works and what does not. We begin by discussing how much effort is required to operate the decision process.

EFFORT REQUIRED TO DO AN EVALUATION

The overall evaluation process was illustrated earlier in Figure 4-1. Sessions lasted about 5 hours, including both introductory presentations and the evaluations per se. Of that total, the evaluations themselves took about 4 hours.

As indicated in Figure 4-1, the time required for post-evaluation analysis was fairly modest.

Since the evaluations in our design depend on the availability of workbooks, related questions are how many different workbooks might be needed, and how long it will take to prepare one. The best answers will come from experience, but these are reasonable extrapolations from the trial application:

◆ One workbook will be needed for each major category of workloads. The major categories of workloads will probably comprise propulsion (covered by the workbook most completely developed as part of this study), integrated electronics, simple electronics, structures, and mechanical components.

◆ Since additional workbooks can be developed by modifying the propulsion example, developing a single workbook should not take more than 3 to 5 days of effort on the part of two or three competent maintenance analysts.

A 4-hour evaluation proceeded by 1 hour of briefings and some prior preparation does not seem exorbitant for a major subsystem. Our expectation is that the *total* repair sector selection decision time and resource commitments, using the model and process described in this report, probably are less intrusive than has historically been the case. The reason is that more of the problem is addressed at one sitting, reducing the need for extended iteration as new questions, not previously considered, are submitted by interested parties.

OVERALL PROCESS EFFECTIVENESS

Generally the evaluation process appeared to provide a reasonably objective way of looking at the key factors that determine a repair sector's ability to meet customer needs. That is, it was a reasonably comprehensive model of the key elements of the public versus private repair sector selection decision.

Further, the evaluators found it of benefit. By addressing notionally all of the relevant considerations—with factors and measurement scales defined—it enabled them to talk to each other about the important issues, rather than past each other. As they perceived it, the structured, joint assessment of each other's capabilities by industry and government yielded a better joint understanding of depot-level repair issues and a better understanding of each other's strengths and limitations.

However, we are not convinced that our process by itself will assure fair or consistent evaluations across the military services and over time. Although it mitigated some sources of bias, others remain or are likely to recur, depending on the particular individuals who participate in the evaluation focus group.

Consistent and fair evaluations would logically depend on these ingredients:

◆ A reasonably comprehensive, fair, and consistent way to look at the repair sector selection decision.

◆ Evaluators who have training and experience to do evaluations well. This training and experience would necessarily cover the relevant technical aspects of maintenance and business practices (management and financial) in both the commercial and government worlds. It would also necessarily include the repair sector selection model and the procedures for evaluating the input factors.

◆ Evaluators who are—and are perceived as being—free of a personal or organizational stake in the outcome.

The experience with the trial evaluations (as well as the history of decision tree analysis) suggests that the second and third criteria are not satisfied. Although practices differ across services, initial RSS decisions are, today, typically made by the staffs of system program offices. These individuals generally lack prior experience in such decisions and/or related training. (With the exception of senior staff, this was the case in the trial applications.) Further, once they make the investment in mastering the process they may not have the opportunity to participate in such decisions again.

There certainly is no cadre of personnel with an understanding of both industry and government capabilities. Traditional decision tree analyses have made the choice between organic and contract repair with little if any private-sector participation. Inevitably, as our experiments tend to confirm, characterizing industry without really understanding its capabilities and limitations results in biased evaluations to the detriment of the final customer.

Although the evaluations described in this report were putatively between the organic and contract repair sector alternatives rather than between specific organic and commercial sources, for two of the subsystems it was reasonably clear who the real stakeholders were on both the organic and contract sides. We were fortunate to obtain the cooperation of industry stakeholders for evaluations in Sessions II and III and the organic stakeholders for all four (with limitations in Session III). The problem is that there will be situations where specific private-sector representation is not practical. An example is where there are multiple potential commercial sources of repair. Similarly, the experience of Session III suggests that adequate knowledge of government capability cannot be assured.

Even where there is prior experience, the provision regarding a lack of conflict cannot be satisfied. For instance, the government personnel we interviewed or worked with during this project generally had an organizational stake in the RSS decision. The resulting problems were readily apparent during the conduct of the

four trial evaluations, particularly Session I: when one side or another comes into a session making it clear from the outset that only one answer will satisfy them, then bias is an inevitable result. A strong and fair government moderator mitigated the problem during Sessions II and III. The problems, however are that

◆ a strong and fair moderator might not always be available and

◆ industry personnel and government personnel may not be peers in terms of education and technical training. When they are not then one set of representatives can outclass the other.

ADDITIONAL NECESSARY PROCESS CHANGES

To resolve the remaining important problems will require a more robust approach than an IPT or focus group. An approach that commends itself is the due diligence procedure that businesses use to study, investigate, and evaluate major business opportunities. The purposes of a due diligence procedure are to

◆ determine (generally through interviews, document study, and on-site inspection) that a business is what it seems or is represented to be;

◆ verify that a proposed investment complies with investor's criteria; and

◆ provide a defense against third-party claims at some later time.[3]

The RSS decision involves very similar considerations—that the commercial and organic sectors are as they appear to be, that one or the other will better fit DoD's criteria for supporting its repair customers, and to document that the RSS decision was fair, impartial, and in the best interest of the repair customer.

Of the characteristics of the ideal due diligence investigator or investigation team, two are particularly relevant here. First, due diligence investigators normally are sufficiently senior that they grasp corporate politics, power structures, cultures, and similar considerations. An investigator who lacks this background might produce a mechanically satisfactory analysis but be unable to provide the broad insight needed for a really sound decision. Second, due diligence investigators are normally unaffected by the outcome of the due diligence process. This provision is necessary to avoid conflicts of interest and help assure objectivity. It is particularly this second provision that we call to attention here. As discussed above, the RSS evaluations that are made today are not accomplished by individuals without a stake in the outcome.

Accordingly, we recommend that DoD borrow from commercial due diligence practice and create an RSS decision support cadre reporting to the Defense Depot Maintenance Council. This cadre should be structured to be

◆ truly without conflict of interest regarding the outcome of RSS decisions and able to maintain the confidence of the competing constituencies as well as of internal and external process or decision critics; and

◆ sufficiently senior and experienced to bring to the RSS analyses the requisite education, technical training, market awareness, and policy perspectives. In particular, there should be no question but that they are on a peer level with their organic depot and commercial industry counterparts.

End Notes for Chapter 4

[1] To illustrate, in 1982, the Office of the Secretary of Defense directed the services to use a decision tree analysis process for repair sector decisions. A 1990 LMI study of Army repair sector decisions could not find evidence that it had been used or disseminated in the Army. Kelvin K. Kiebler, Larry S. Klapper, and Donald T. Frank, *Army Depot Maintenance: More Effective Use of Organic and Contractor Resources*, LMI AR803R1, June 1990, p. 2-20;

The 1994 Defense Science Board study stated that the services had and used decision tree analyses but that the processes were inconsistent with the CORE concept. Office of the Under Secretary of Defense for Acquisition and Technology, *Report of the Defense Science Board Task Force on Depot Maintenance Management*, April 1994, Appendix E.

[2] These were selfishness and guile, impression management, information availability, misinterpretation, and failure to seek evidence to the contrary. See Table 3-1.

[3] Gordon Ring, *Due Diligence Techniques and Analysis*, Westport, CN: Quorum Books, 1996, pp. 2, 52.

Appendix A
Mathematical Form of the Model

INTRODUCTION

Chapter 2 of this report described a conceptual model of the repair sector selection decision that included three sets of elements:

◆ Needs of the end-users of depot repair services (e.g., timeliness, low cost, quality)

◆ Characteristics of the two repair sectors relevant to satisfying user needs (e.g., adequate capability and capacity, scope and scale economy, responsiveness)

◆ Factors that determine the characteristics of the repair sectors. Such factors fall into three categories, according to whether they

➤ are intrinsic to the nature of the repair sources themselves,

➤ depend on the relationship between the repair source and the buyer of repair services, or

➤ are a function of the repair work to be accomplished.

The conceptual model has at its starting point the determination of a repair sector's ability to satisfy repair customer needs. However, because of the many factors that come into play, it is too simplistic to think of that ability as a yes-or-no proposition. Rather, what we are interested in is the degree to which one repair sector will probably satisfy customer needs when compared to another, i.e., the relative risk of each sector. To establish that each of the needs, characteristics, and factors is a legitimate element in determining repair sector risk, Chapter 2 presented support from previous depot maintenance studies, from the relevant general literature, or both. To test the conceptual model we implemented it in a mathematical form and then used that to run trial applications on three different V-22 aircraft workloads. This appendix describes the mathematical form of the model.

Prior to describing the source of model, we first describe the alternative approaches considered and the one that forms the basis for the model. We then show how that approach was implemented in the repair sector selection decision model.

MATHEMATICAL MODELING APPROACH

Five primary considerations were important to the choice of mathematical form:

1. The mathematical approach needed to accommodate economic factors such as capacity in excess of workload and noneconomic factors such as customer knowledge.

2. Most of the factors, both economic and noneconomic, were more qualitative in nature than quantitative—thus a mechanism for converting from qualitative (verbal) to quantitative judgments was needed.

3. During acquisition of new weapon systems and modifications, when this methodology is to be applied, even notionally quantitative data are notoriously soft. Thus the mathematical approach needed to accommodate uncertainty.

4. For a complex weapon system many repair sector selection decisions will be made. This means that for any single repair sector selection decision the effort needed to gather input data has to be modest.

5. In practice, the analysis work behind repair sector selection decisions is decentralized to individual program offices. Therefore, it was important to develop a mathematical form that program offices could use without help from the analysts that created it.

With these considerations in mind, we examined alternative mathematical modeling approaches (summarized in Table A-1).

Simulation, optimization, and *expert systems* are relatively familiar modeling methods. The first two are extensively used in logistics. Expert systems are a more recent addition to the analyst's tool bag but are now well covered in the literature on decision support systems[1] and have documented application in logistics.[2]

Multiattribute utility theory (MAUT) is a technical name for the scoring models often used to select among policy alternatives. Typically such scoring models identify relevant criteria, assign importance weights to them, judgmentally score each alternative against the criteria, then multiply weights times scores and add the results to determine the preferred alternative. This approach was used, as an example, on depot maintenance management options in the 1993 *Integrated Management of Department of Defense Depot Maintenance Activities* study.[3] Contractor source selection also uses this approach widely.[4] In decomposing a problem into a number of dimensions that are considered individually, MAUT models are not necessarily better or more accurate than a global assessment. They do have the advantage of being informative and increasing understanding of a problem under consideration.[5]

Table A-1. Alternative Mathematical Modeling Approaches

Approach	Advantages	Disadvantages
Simulation	• Easy to analyze flows, cycles, and costs • If graphical, aids in visualization of material flows	• Hard or impossible to capture qualitative technical, programmatic, and policy factors • Requires continuing support from analyst
Optimization	• Can include qualitative and subjective factors	• Can be hard to understand and explain (black box with complicated mathematics) • Requires continuing support from analyst
Expert systems	• In its rule-based form automates decision tree logic • Can include all relevant factors	• "Brittleness"—i.e., tendency to give nonsense answers outside narrow domain for which designed; probably not suitable for this broad a domain • Requires assistance from analyst/knowledge engineer to modify
Multiattribute utility theory (MAUT)	• Can include all relevant factors • Reasonably easy to modify	• Easy to get lost in details, forget what the question was • Does not lend itself to collaborative thinking
Analytic hierarchy process (AHP)	• Can include all relevant factors • Reasonably easy to modify • Provides means for averaging judgment errors	• Easy to get lost in details • Can be exhausting to do the many paired comparisons required • Hard to use collaboratively
Quality function deployment	• Graphical nature makes it easier to keep track of big picture • Lends itself to collaborative thinking • Good track record on analogous problems	• Newer in the United States and less well-known than other methodologies • Implementing companies have viewed its use as a competitive advantage, limited the number of published results

The *analytic hierarchy process* (AHP) works similarly, in that it decomposes a problem into a number of dimensions, determines criteria weights for each of the dimensions, and evaluates alternatives against criteria.[6] A prominent difference is that it aids in the assignment of weights and evaluations, by comparing the criteria against each other two at a time and then comparing alternatives against criteria two at a time. This pair-wise comparison, although tedious, can help compensate for individual errors in judgment through a mathematical procedure for essentially averaging errors.

The newest decision support method we considered is *quality function deployment* (QFD).[7] Although the literature on QFD tends to emphasize its application rather than its mathematical basis, examination of the inner workings shows it to be based on multiattribute utility theory. One may think of QFD as a graphical and strongly customer-oriented instance of MAUT.

The advantages and disadvantages shown in Table A-1 are in part a compilation of those documented in the literature.[8] But they also reflect our own experience with these techniques in the areas of reliability and maintainability investments, logistics technology choices, selection of management strategies, and other decision environments relevant to the repair sector choice.

The five considerations enumerated above, and an understanding of the environment in which the methodology would be used, informed the mathematical approach chosen. We eliminated simulation as the primary tool because of its inability to handle the many qualitative factors. Although optimization can handle qualitative factors (after conversion to quantitative equivalents), we eliminated optimization models because of their complexity and the continuing analyst support they would need. Expert systems are not a viable candidate, in our estimation, because the problem domain is broad rather than narrow and expert systems do poorly with broad problems.

Our choice is what amounts to an extension of the quality function deployment methodology. QFD's strong customer orientation is particularly useful for repair sector selection decisions, as is its graphical presentation. We extended QFD in three ways:

◆ First, the internal arithmetic in commercially available QFD software, consistent with the notion of quality function deployment *from* the customer *to* the provider, generally determines the importance of proposed factors that enter into satisfying customer needs. It does not provide a means for projecting how well the customer's needs are actually met. However, a comparative risk assessment requires some measure of how well customer needs are met. In this implementation, we can also start with an assessment of each repair sector against the factors and then estimate how well each repair sector will satisfy each of the customers' needs.

◆ Second, in common with MAUT generally, QFD provides unitless relative ratings (e.g., 0.9, 2.6, 7.3). A relative rating of, say, 2.63 for one repair sector and 2.72 for another only establishes that one rating is higher than the other, not what the significance of the difference is, or even whether a repair sector is high or low risk. We compare individual evaluation results to the expected results of many similar evaluations. (Since the methodology developed in this report is new, no historical data exist for similar evaluations against which to compare. We developed a simulation to artificially create such a background.) This comparison against expected results permits us to say whether either sector carries a high or low risk. For display purposes, we used a combination of numerical, adjectival, and color-coding ratings similar to those employed in source selections.[9]

◆ Third, the literature on QFD offers little guidance on how to elicit weights and evaluations. (The literature on MAUT does provide some guidance.)

Further, such judgments are known to be subject to bias unless particular attention is paid to elicitation methods.[10] For this reason, our repair sector evaluation procedure includes an evaluation workbook and standardized rating scales.

REPAIR SECTOR SELECTION DECISION MATHEMATICAL MODEL

A top-level view of a small portion of the QFD-based repair sector selection decision model is shown in Figure A-1.

Figure A-1. Quality Function Deployment Model
for Evaluating Alternative Sources of Repair
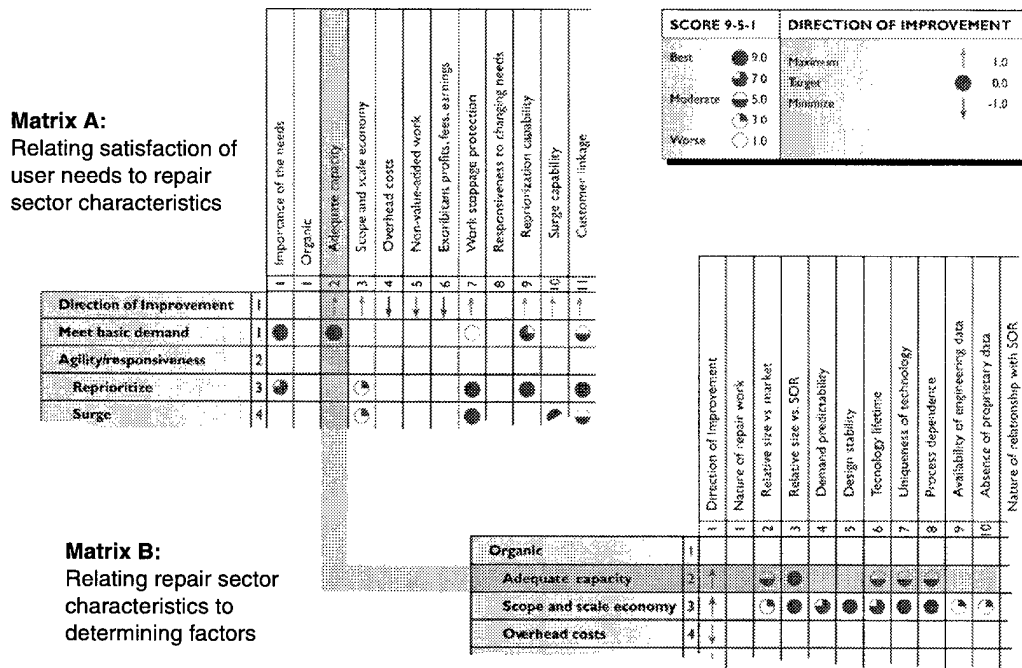
There are two linked QFD matrices. Matrix A relates customer needs to repair sector characteristics. Matrix B relates the characteristics of the repair sectors to the factors that determine those characteristics. The matrices operate as follows:

◆ The columns of Matrix A are the rows of Matrix B.

◆ The symbols in the third column of Matrix A indicate the relative importance of the various customer needs. A solid dot is a "9," meaning very important. Similarly, a three-quarters dot is a "7."

◆ The symbols at the intersections of needs and characteristics in Matrix A represent strengths of interaction between needs and characteristics—i.e., weights—which determine the relative importance of the various characteristics. For instance, a solid dot indicates a weight of "9," and an open dot indicates a weight of "1."

◆ The symbols at the intersections of characteristics and factors in Matrix B operate identically to those in Matrix A.

We developed the repair sector evaluation model relationships and weights using commercial QFD software called QFD/Capture.[11]

Figure A-2 partly illustrates the internal logic of the QFD model. It indicates that ability to meet basic demand depends on capability and capacity, work stoppage protection, ability to reprioritize, and customer linkage (knowledge of the customer's requirements). Similarly, capability and capacity to do the work are influenced by the extent to which the work is process-dependent, the scope of the relationship between the government acquiring agency and the source of repair, availability of more than one source of repair, as well as product knowledge.

Figure A-2. Tree Representation of the Model
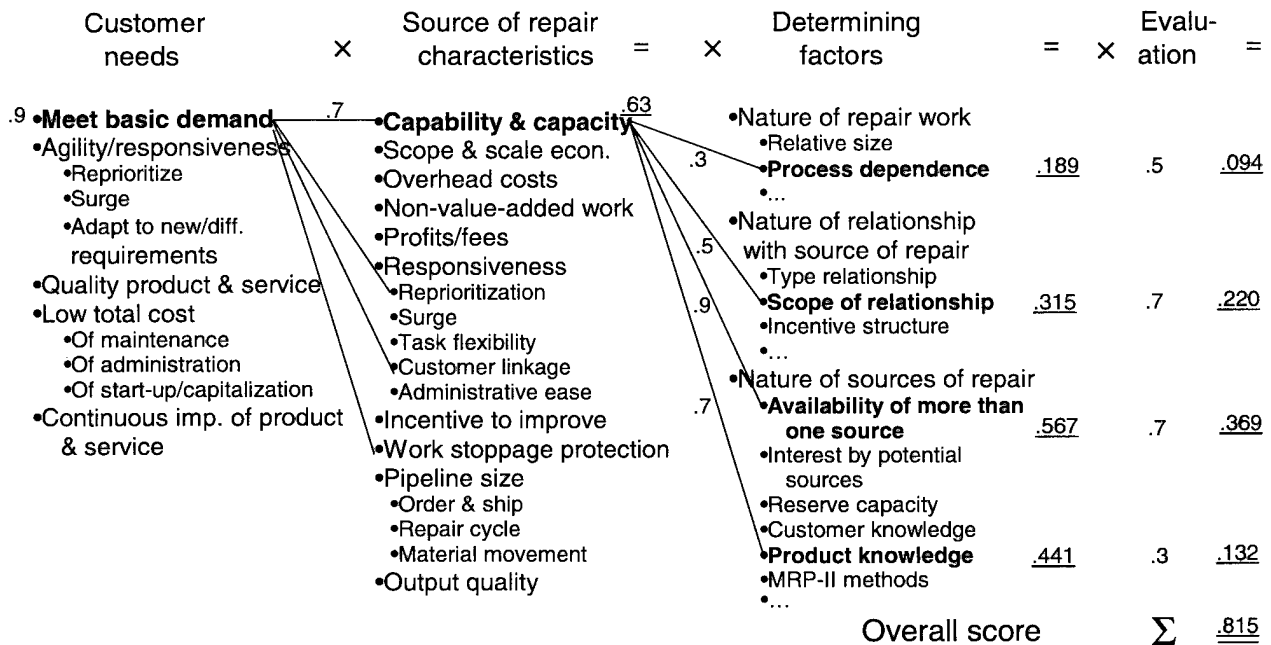
As described in Chapter 2 and illustrated here, determining factors may be a function of the repair work itself; or may depend on the nature of the relationship between the source of repair and the government agency acquiring repair services for the customer; or may be directly related to sources of repair themselves.

Calculation on Figure A-2 proceeds from left to right. If the notional importance of meeting basic demand were .9 and the relationship weights are as shown in Figure A-2, then the calculated factor weights (the relative importance of the determining factors) are as shown in Table A-2.

Table A-2. Example Calculation of Factor Weights for Meeting Basic Demand

Factor	Calculation	Result (factor weight)
Process dependence	$0.9 \times 0.7 \times 0.3$	0.189
Scope of relationship	$0.9 \times 0.7 \times 0.5$	0.315
Availability of more than one source	$0.9 \times 0.7 \times 0.9$	0.567
Product knowledge	$0.9 \times 0.7 \times 0.7$	0.441

The reason for calculating the relative importance of the determining factors is to provide a basis for comparing repair sectors. To illustrate, suppose that the known pragmatic choices were the following:

◆ Commercial sector

➤ Original Equipment Manufacturer (OEM)

➤ Third-party sources of repair

◆ Organic sector

➤ A maintenance depot that has a long history of experience in similar systems.

The OEM probably has excellent product and process knowledge. An organic source would have some product and process knowledge and would have to be provided additional information. Third-party sources might have limited initial knowledge. Further, suppose that these qualitative comparisons are converted into numerical scores of 0.9, 0.7, and 0.5, respectively. Then the calculations for product knowledge might be as shown in Table A-3.

Table A-3. Example Factor Calculations for Product Knowledge

Source of repair	Product knowledge assessment	Product knowledge score	Product knowledge factor weight	Result of multiplying score and weight
OEM	Excellent	0.9	0.441	0.397
Organic	Some knowledge has to be provided	0.7	0.441	0.309
Third party	Limited knowledge	0.3	0.441	0.132

Table A-3 provided sample calculations for a single factor. Overall results are obtained by adding the results for the different factors. Table A-4 illustrates for a subset of three factors. Considering only this subset of factors, the organic choice would be preferred since it has the highest score, 1.312. (In this case, however, the organic choice dominated both commercial sector possibilities—which might not always be the situation.)

Table A-4. Example Factor Aggregation for Three Factors

Source of repair	Results of multiplying factor scores by factor weights for three factors			Total score
	(A) Scope of relationship	(B) Availability of more than one source	(C) Product knowledge	(A+B+C)
OEM	0.443	0.134	0.397	0.974
Organic	0.567	0.436	0.309	1.312
Third party	0.220	0.369	0.132	0.721

The approach illustrated thus far, which follows the typical QFD "forward" calculation flow from customer needs to the evaluation factors, provides an overall grand total for each of the potential repair sectors. It does not reveal how well each of the original customer needs (i.e., meet basic demand, agility/responsiveness, quality product and service, ...) was satisfied. In the model we provided that capability as well.

End Notes for Appendix A

[1] Cf. Efraim Turban, *Decision Support and Expert Systems: Management Support Systems,* New York: Macmillan, 1990, pp. 423–447.

[2] Mary K. Allen and Omar Keith Kelferich, *Putting Expert Systems to Work in Logistics,* Oak Brook, IL: Council of Logistics Management.

[3] Office of the Secretary of Defense (Logistics), *Integrated Management of Department of Defense Depot Maintenance Activities,* Vol. 1: Study Results, October 1993, pp. 5-7–5-21.

[4] U.S. Army Materiel Command Pamphlet 715-3, Vol. 5, *The Best Value Approach to Selecting a Contract Source,* August 1994, pp. 8–14.

[5] Lennart Sjoberg, "Aided and Unaided Decision Making: Improving Intuitive Judgment," *Journal of Forecasting,* Vol 1. (1982), pp. 349–363.

[6] Saul I. Gass, *Decision Making, Models and Algorithms: A First Course,* New York: John Wiley & Sons, 1985, pp. 355–364.

[7] James L. Bossert, *Quality Function Deployment: A Practitioner's Approach,* Milwaukee: ASQC Quality Press, 1991;

Lawrence R. Guinta and Nancy C. Praizler, *The QFD Book: The Team Approach to Solving Problems and Satisfying Customers Through Quality Function Deployment,* American Management Association, 1993.

[8] Turban, *Decision Support Systems,* pp. 1–104; Allen and Kelferich, *Putting Expert Systems to Work in Logistics;*

Peter G. W. Keen and Michael S. Scott Morton, *Decision Support Systems: An Organizational Perspective,* Reading, MA: Addison-Wesley, 1978;

Bossert, *Quality Function Deployment,* 1991;

Lawrence R. Guinta and Nancy C. Praizler, *The QFD Book: The Team Approach to Solving Problems and Satisfying Customers Through Quality Function Deployment,* American Management Association, 1993;

Barry G. Silverman, "Unifying Expert Systems and the Decision Sciences," *Operations Research,* Vol. 42, No. 3, May–June 1994, pp. 393–414;

Mathew J. Liberatore and Anthony C. Stylianou, "Expert Support Systems for New Product Development Decision Making: A Modeling Framework and Applications," *Management Science* Vol. 41, No. 8, August 1995, pp. 1296–1316.

[9] U.S. Army, *Best Value Approach,* p. 10.

[10] Cf. James G. March and Zur Shapira, "Managerial Perspectives on Risk and Risk Taking," *Management Science,* Vol. 33, No. 11, November 1987, pp. 1404–1418;

Cf. John D. Sterman, "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment," *Management Science,* Vol. 35, No. 3, March 1989, pp. 321–339.

[11] QFD/Capture is developed and marketed by International TechneGroup, Incorporated, Milford, Ohio. We used version 3.1.

Appendix B
Assumed Distributions for Evaluation Factors

As described in Chapter 3 of this report, an approach to establishing significance of a repair sector rating is to recognize that if the results of many such ratings were available then the pattern of results would form a backdrop against which any individual rating could be viewed. However, the results of many such analyses are not available. Nonetheless, it is possible to artificially create a backdrop of results by simulating the performance of a large number of analyses. Doing so involves randomly choosing input factors from pre-established "reasonable" statistical distributions for each of the evaluation factors. This appendix documents assumed distributions for the evaluation factors. This appendix comprises three sections:

- ◆ Factors related to the nature of the work to be performed

- ◆ Factors related to the relationship with potential sources of repair

- ◆ Factors related to the nature of potential sources.

These sections (labelled III, IV, and V) correspond to the equivalent sections in the evaluation workbook that is also included with this report (Appendix C).

The assumed distributions in this appendix are applicable to propulsion workloads and require modification for other types of repair work. These distributions are the product of Logistics Management Institute staff members who have experience with propulsion systems and depot maintenance. Effort was made to ensure these distributions are reasonable but it should be recognized that they are the product of human judgment rather than statistical analysis.

SECTION III: EVALUATION—NATURE OF WORK TO BE PERFORMED

III-1. Relative size (amount) of this workload compared to total market. Includes organic and private-sector marketplaces.

| This workload is the total market. No other similar workload exists anywhere.

(1) | Total market includes other similar work that may be partially commercial. This workload is the driver—greater than 50%.

(3) | Total market includes other similar work with approximately equal proportions of military and commercial work.

(5) | This workload is in the commercial mainstream. Absence or presence of this workload would have no significant effect on the market.

(9) |

```
|———————|———————|———————|———————|
1       3       5       7       9
```

Probability

B-2

Comments:

- ◆ "Typical" DoD gas-turbine engine depot workload is a small amount (e.g., less than 25 percent) of the worldwide gas-turbine engine depot workload.

- ◆ A 1 rating is unlikely because all military engines have some commonality with other military or commercial engines.

- ◆ A 3 rating is also unlikely because we did not see any cases where the workload, by itself, would be the driver of the engine remanufacturing market.

- ◆ A 9 rating is a small possibility because:

  - ➤ Absence or presence of the workload could have a minor affect on the market.

  - ➤ The majority of DoD's propulsion workload is close to the commercial mainstream even though some possible configuration changes may make the engine difficult to support commercially.

III-2. Relative size (amount) of this workload compared to a typical source of repair's total workload.
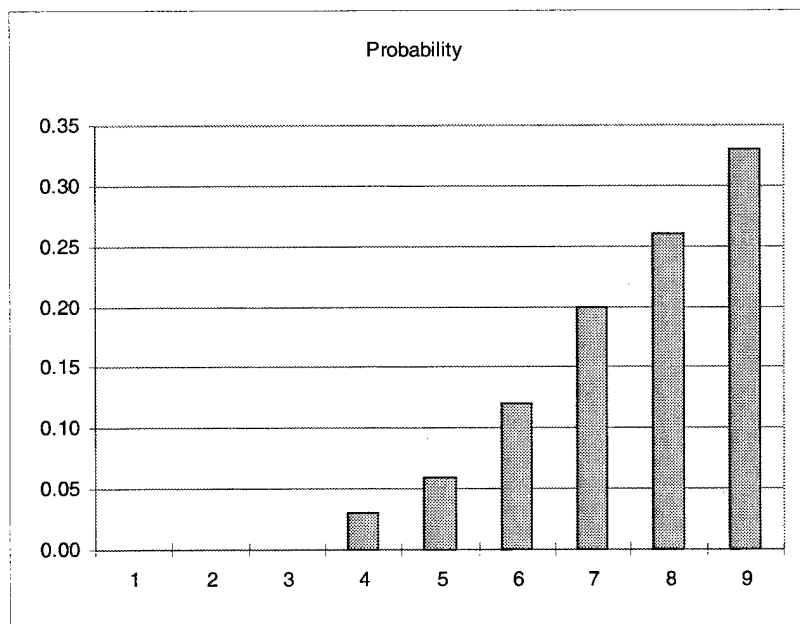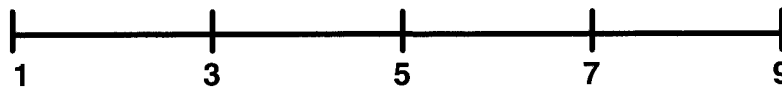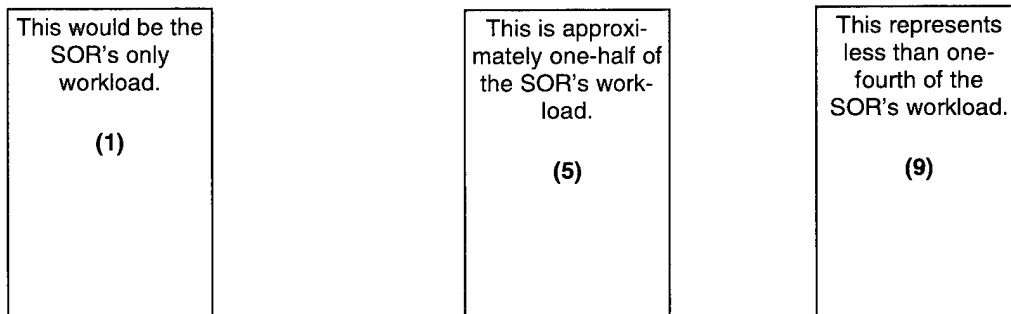
This would be the SOR's only workload. (1)		This is approximately one-half of the SOR's workload. (5)		This represents less than one-fourth of the SOR's workload. (9)

```
├──────┼──────┼──────┼──────┤
1      3      5      7      9
```

Probability

Comments:

◆ The DoD workload is assumed to be gas-turbine engine remanufacturing.

◆ It is unreasonable to expect the workload would be assigned to a source of repair that does not currently accomplish gas-turbine remanufacturing (a 1 is therefore eliminated).

◆ The resulting scale is bounded on the left at 3 and continues up to 9 reflecting DoD's workload representing a range of over one-half to less than one-fourth of a typical source of repair's total propulsion workload.

III-3. Demand predictability.

Forecasting of little or no avail. The peaks and valleys of workload are extreme. The best plan is flexibility to react. **(1)**	Forecasting of some use. Workload will vary from calendar quarter to quarter. **(5)**	Has peaks and valleys but amount of workload consistent from one calendar quarter to another. **(7)**	No surprises. Forecast workload and actual workload are essentially identical (e.g., time change items). **(9)**

```
  ├──────┼──────┼──────┼──────┤
  1      3      5      7      9
```

Probability

Comments:

◆ The demand predictability of propulsion workload is considered in its entirety—not the demand predictability of a single engine. Therefore the greater the number of engines in the work package, the greater the probability that the peaks and valleys of individual engine remanufacturing actions would be evened out.

◆ Based on the above, the end anchors of 1 and 9 are eliminated and the mode is 6.

III-4. Design stability. Changes resulting from functional enhancements, reliability improvements, etc., that affect the repair process (e.g., change form, fit, or function). Excludes design changes that do not affect the repair process.

Design evolving, changes affecting the repair process a certainty. (1)	Some possibility of changes that affect the repair process. (5)	No changes envisioned that affect the repair process. (9)

```
 |------|------|------|------|
 1      3      5      7      9
```

Probability
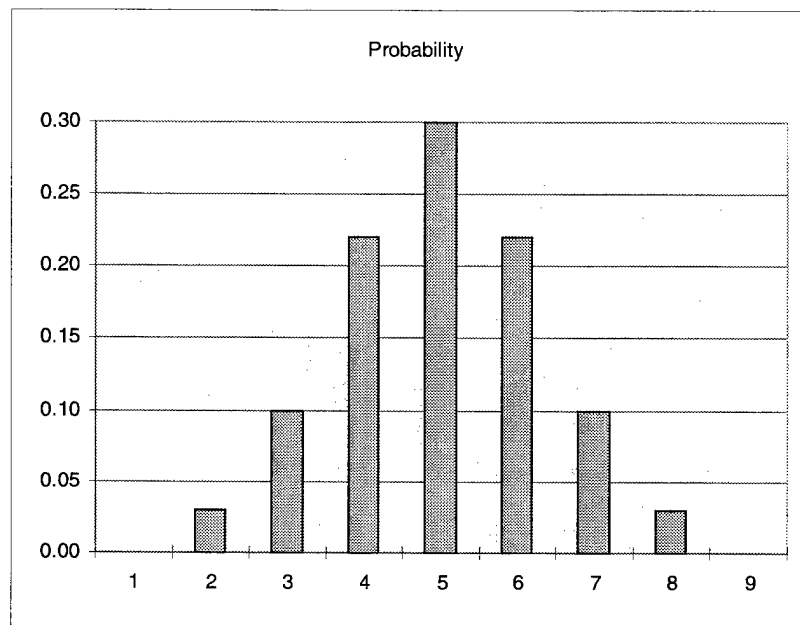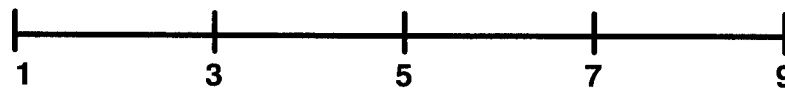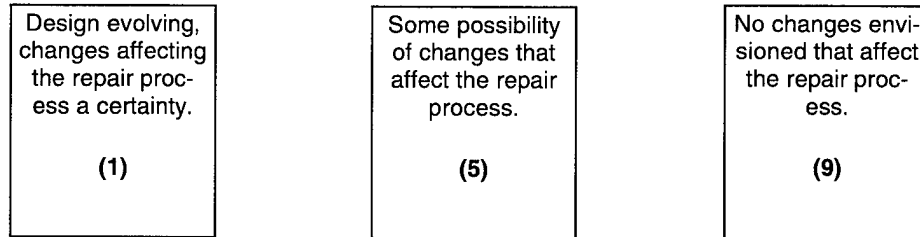
Comments:

◆ A center 5 distribution is anticipated because, for gas-turbine remanufacturing workload, there is some possibly that design changes may arise that will impact the repair process.

◆ The anchors of 1 and 9 are eliminated because there is no absolute certainty that design changes affecting the repair process will or will not occur. All other ratings are possibilities.

III-5. Technology renewal rate. How often does one generation of technology replace another?

| Greater than 10 years.

(1) | About 5 years.

(5) | Less than 3 years.

(9) |

```
  |———————|———————|———————|———————|
  1       3       5       7       9
```

Probability
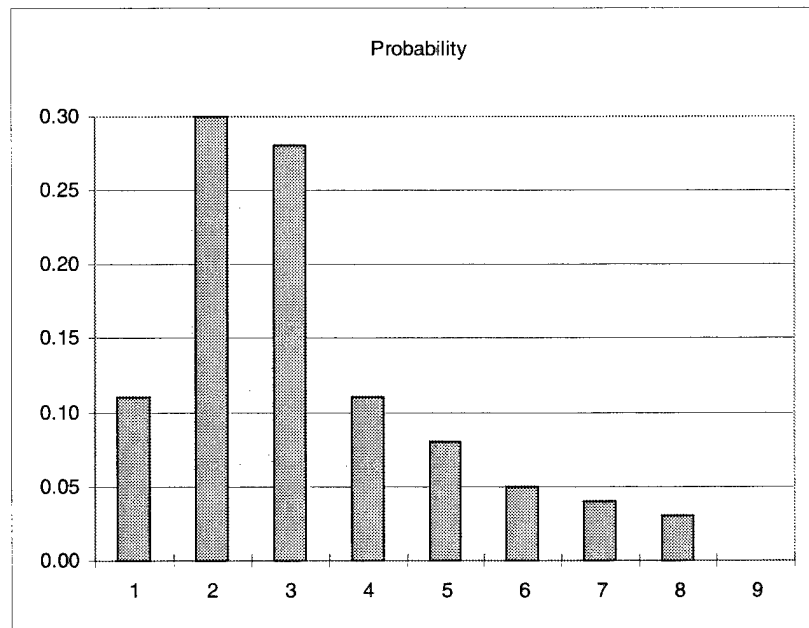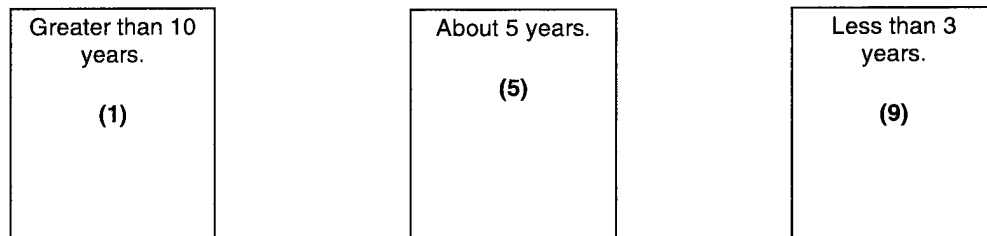
Comments:

◆ The technology renewal rate for gas-turbine engines is normally slow relative to the more electronic/computer intensive systems/components. An anchor of 9 is therefore unlikely.

◆ A renewal rate of slightly less than 10 years is considered the norm.

III-6. Uniqueness of technology.

Unique military technology with few other appli-cations. (1)	Primarily military technology but many different applications. (5)	In mainstream, many applica-tions beyond military. (9)

```
|————————|————————|————————|————————|
1        3        5        7        9
```


Probability
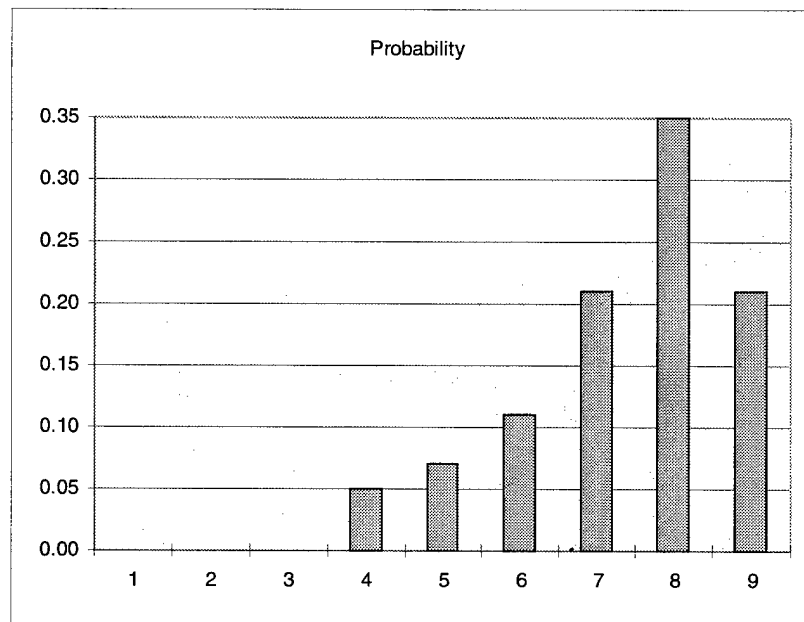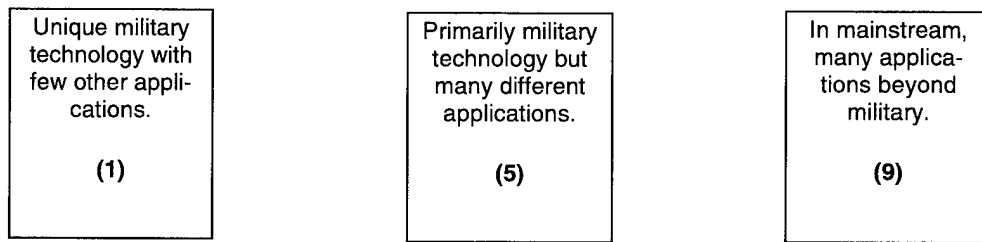
Comments:

◆ Gas-turbine engine technologies are not military-unique.

◆ The majority of DoD's propulsion workload is close to the commercial mainstream and a modal rating of 8 is anticipated.

III-7. Repair process dependence. (Repair process includes skills, training, data, equipment, environment, facilities, etc.)

Repair is dominated by unique repair processes applicable only to this workload. **(1)**	Requires some unique processes. **(5)**	Uses common, widely available processes. **(9)**

```
|--------|--------|--------|--------|
1        3        5        7        9
```

Probability
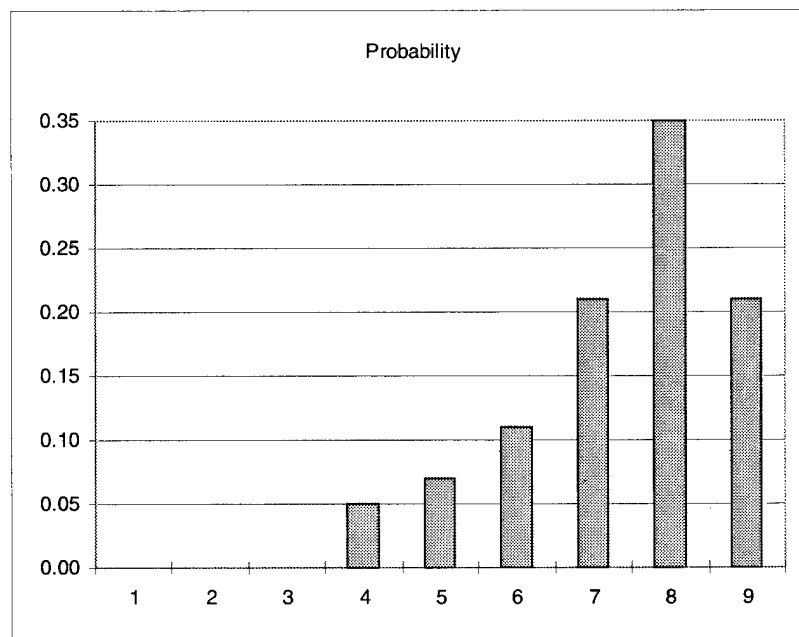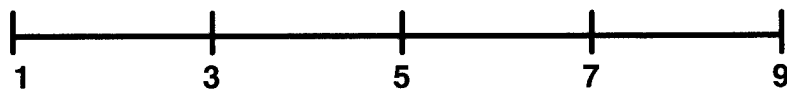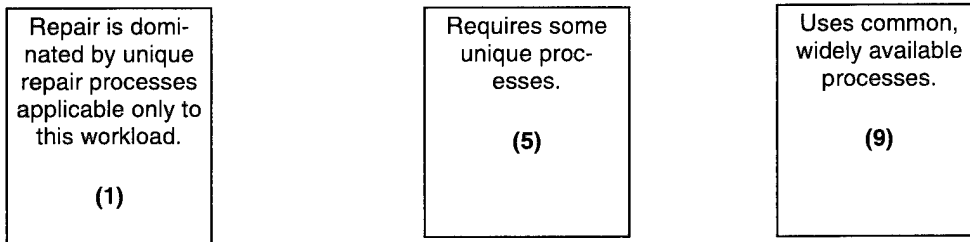
Comments:

◆ Very few unique repair processes are required.

III-8. Availability of engineering data to design repair process. Does it exist?

| Reverse engineering required to develop and maintain repair capability. (1) | Reverse engineering required to augment available data. (5) | Adequate data available to develop and maintain repair process without reverse engineering. (9) |

```
1        3        5        7        9
```

Probability - New System

```
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
      1    2    3    4    5    6    7    8    9
```

B-11

Probability - Existing System
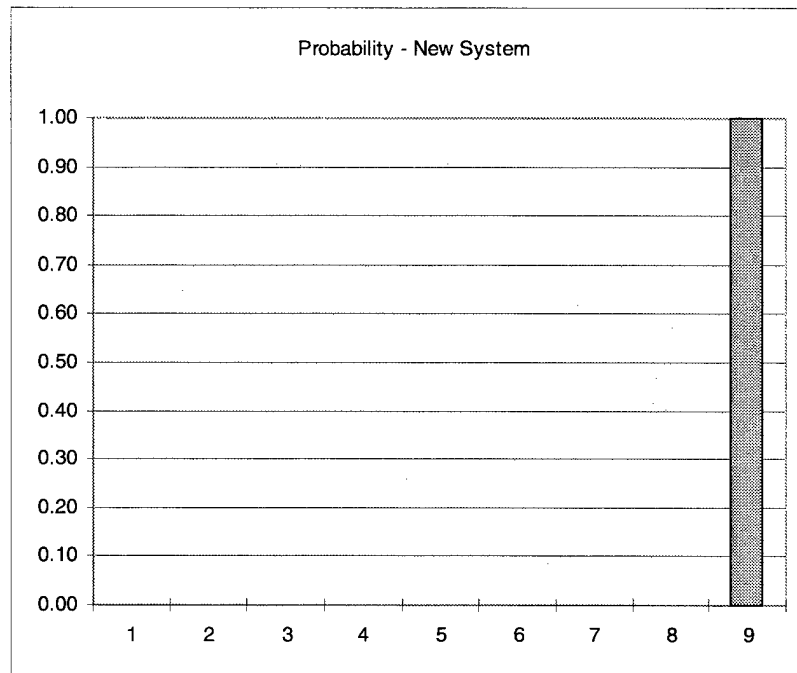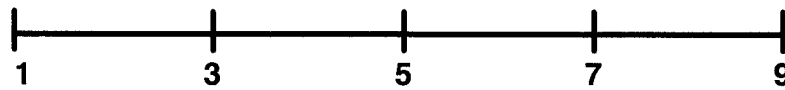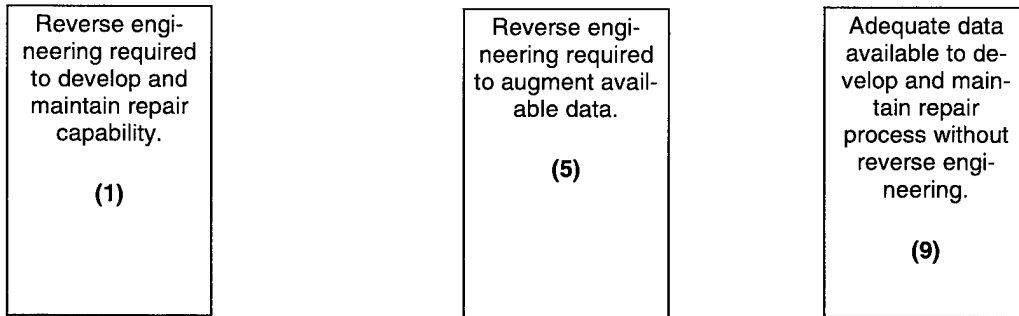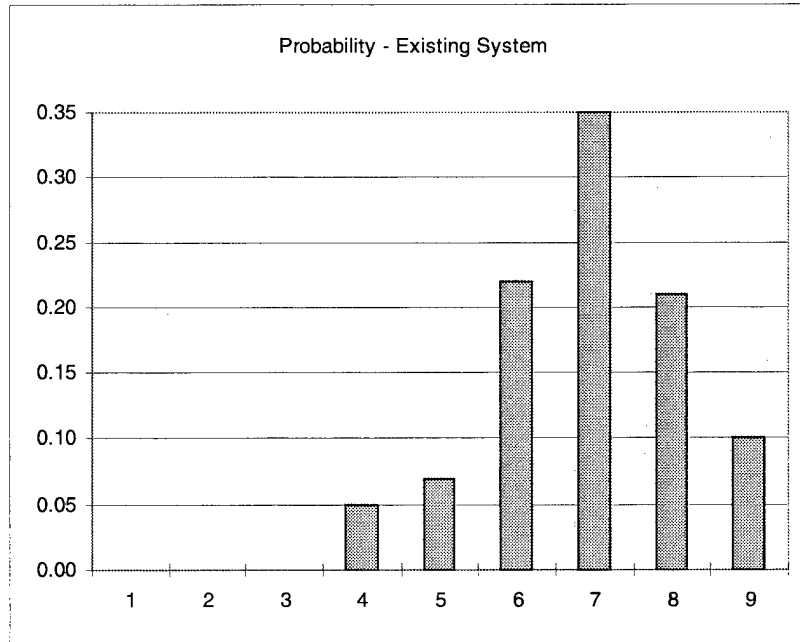
Comments:

◆ For newly acquired propulsion systems, engineering data would always exist at the OEM.

◆ For existing systems, the likelihood is that engineering data exists (a mode of 7); however, reverse engineering could be required if, for instance, data had not been acquired or maintained.

III-9. Absence of proprietary data that affects the design of repair process.

| Proprietary data is required. OEM (or subcontractor to OEM) will not release proprietary data to this source under acceptable terms.

(1) | Proprietary data required—OEM (or subcontractor to OEM) will negotiate rights with this source.

(5) | No proprietary data impacts.

(9) |

```
|———————|———————|———————|———————|
1       3       5       7       9
```


Probability
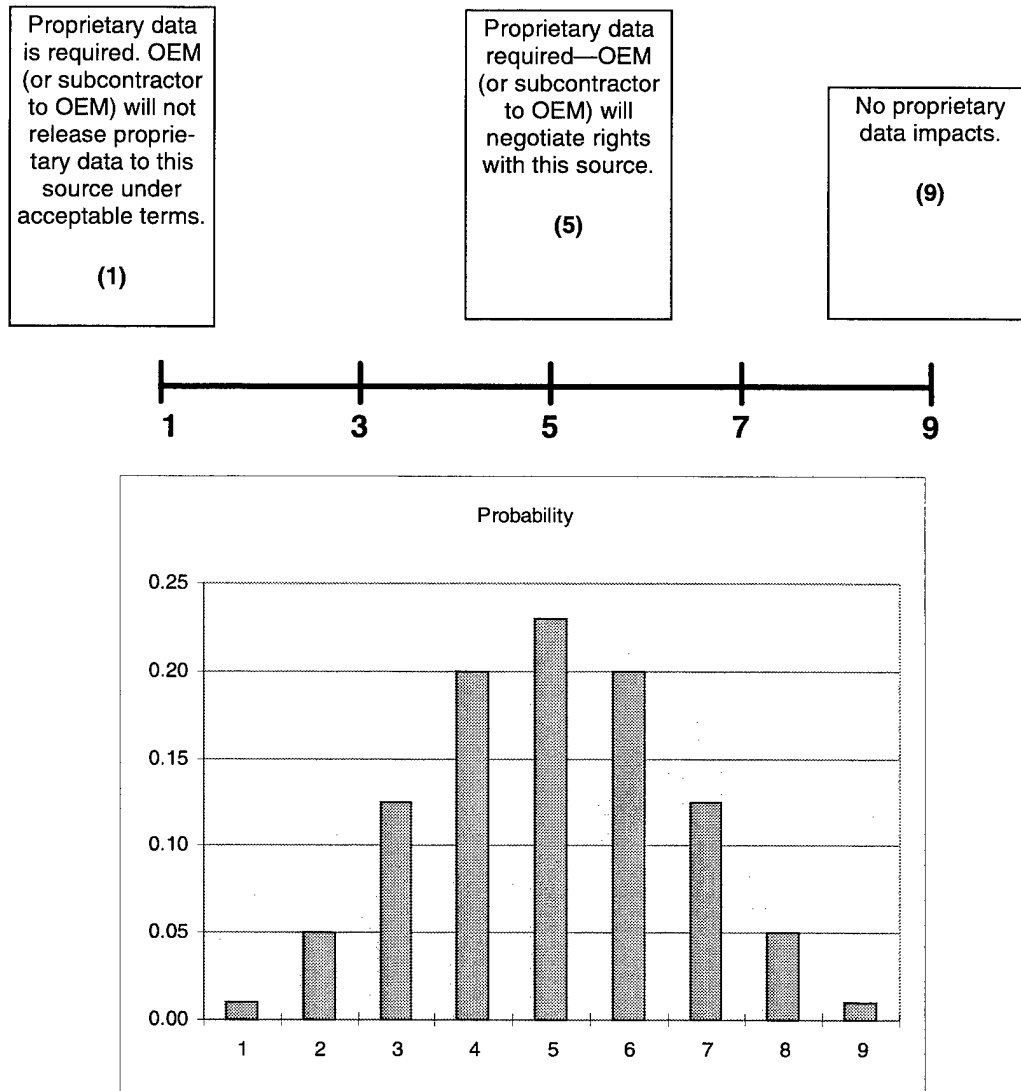
Comments:

◆ A normal distribution is anticipated for new systems with both a 1 and 9 possible. The distribution is expected to be centered at 5.

◆ An important factor in determining whether the distribution shifts up (toward a 9) or down (toward a 1) is whether the likely source of repair is also the OEM.

➤ If the OEM is also the likely source of repair, fewer proprietary impacts are anticipated.

SECTION IV: EVALUATION—NATURE OF RELATIONSHIP WITH SORS

IV-1. Ability to change requirements. Depends upon the flexibility of the relationship between buyer of repair services and typical or likely source of repair.[1]
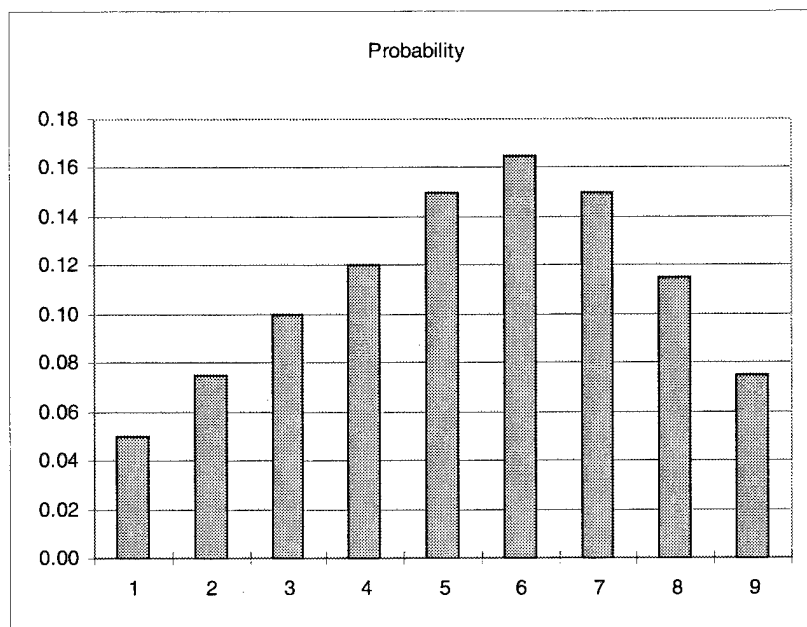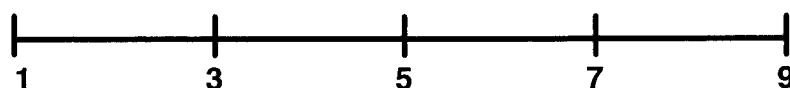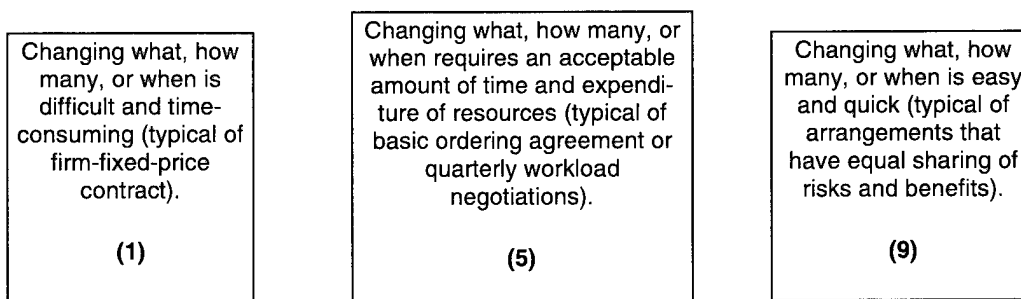
| Changing what, how many, or when is difficult and time-consuming (typical of firm-fixed-price contract).

(1) | Changing what, how many, or when requires an acceptable amount of time and expenditure of resources (typical of basic ordering agreement or quarterly workload negotiations).

(5) | Changing what, how many, or when is easy and quick (typical of arrangements that have equal sharing of risks and benefits).

(9) |

```
├───────┼───────┼───────┼───────┤
1       3       5       7       9
```

Probability

---

[1] Basis of relationship may be formal or informal (e.g., firm-fixed-price contract, basic ordering agreement [BOA], memorandum of agreement [MOA], organic production schedule, etc.).

Comments:

◆ Because a wide range of formal and informal relationships can exist between the DoD buyer of repair services and a source of repair, the full range of assessments are possible.

◆ Item managers, if asked, would probably assign a rating of 5 anticipating expending time and effort to make changes.

◆ Potential source's of repair, if asked, would probably rate themselves a 7 or 9 believing they are flexible.

IV-2. Scope of relationship. What is the intended work package (how many reparable items are in the work package that use complementary repair processes and resources)?

| Only one reparable item is included in the work package.

(1) | Two or three reparable items are included in the work package.

(3) | Between four and eight reparable items are included in the work package.

(5) | Between nine and nineteen reparable items are included in the work package.

(7) | Twenty or more reparable items are included in the work package.

(9) |

```
|----------|----------|----------|----------|
1          3          5          7          9
```

Probability

```
0.35 |                                    ___
     |                                   |   |
0.30 |                                   |   |
     |                                   |   |
0.25 |                                   |   |
     |                              ___  |   |
0.20 |                             |   | |   |  ___
     |                             |   | |   | |   |
0.15 |                             |   | |   | |   |
     |                        ___  |   | |   | |   |
0.10 |                       |   | |   | |   | |   |
     |                  ___  |   | |   | |   | |   |
0.05 |             ___ |   | |   | |   | |   | |   |
     |            |   ||   | |   | |   | |   | |   |
0.00 |_____|___|____|___|__|___|_|___|_|___|_
        1    2    3    4    5    6    7    8    9
```

Comments:

◆ An assumption is made that the gas-turbine engine undergoing remanufacturing is disassembled thus receiving benefits from vertical scope of relationship. For example, turbine blades are cleaned, inspected, and possibly repaired using similar processes.

◆ Because of the above assumption, the mode would be an 8.

IV-3. Typical source of repair's direct responsibility for materiel management, sustaining engineering, distribution, and transportation.

Responsibility limited to repair. The SOR has no responsibility for nonrepair functions. **(1)**	Responsibility includes repair and some of the four related functions. **(5)**	Responsibility includes repair and all four related functions. **(9)**

```
├─────────────┼─────────────┼─────────────┼─────────────┤
1             3             5             7             9
```

Probability

1	2	3	4	5	6	7	8	9

Bar chart values (Probability):
- 1: 0.00
- 2: 0.00
- 3: 0.03
- 4: 0.10
- 5: 0.18
- 6: 0.26
- 7: 0.18
- 8: 0.15
- 9: 0.10
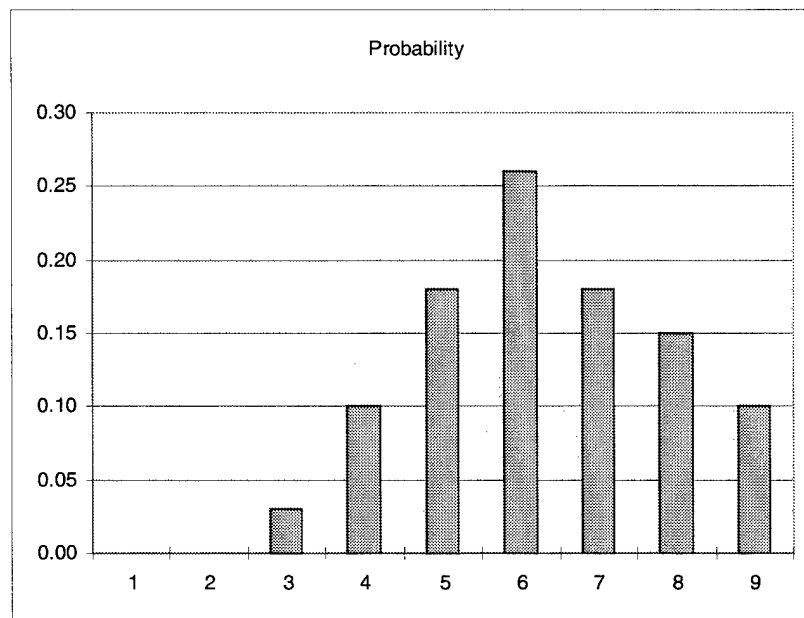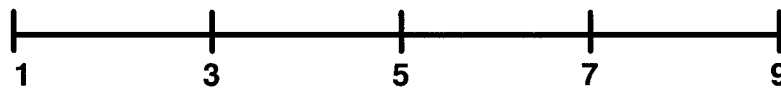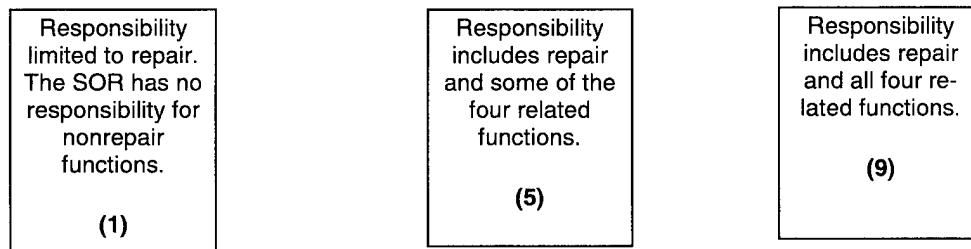
Comments:

◆ Because of the nature of propulsion remanufacturing, DoD will always assign some engineering responsibilities to a source of repair; therefore the low anchor (1) is not anticipated.

◆ It is anticipated that the source of repair will accomplish some, if not all, of the related functions.

IV-4. Policy on reparable lot sizes. What lot sizes are likely to be presented to a typical source of repair?

Workload accumulates. Nothing is released to repair process until some preset quantity of repa- rables are on hand. **(1)**		Monthly induction where the quantity inducted is based on user needs. **(5)**		Every individual failure in the field triggers an immediate repair re- sponse. **(9)**

```
 ├──────────┼──────────┼──────────┼──────────┤
 1          3          5          7          9
```

Probability

0.18	
0.16	
0.14	
0.12	
0.10	
0.08	
0.06	
0.04	
0.02	
0.00	

1   2   3   4   5   6   7   8   9
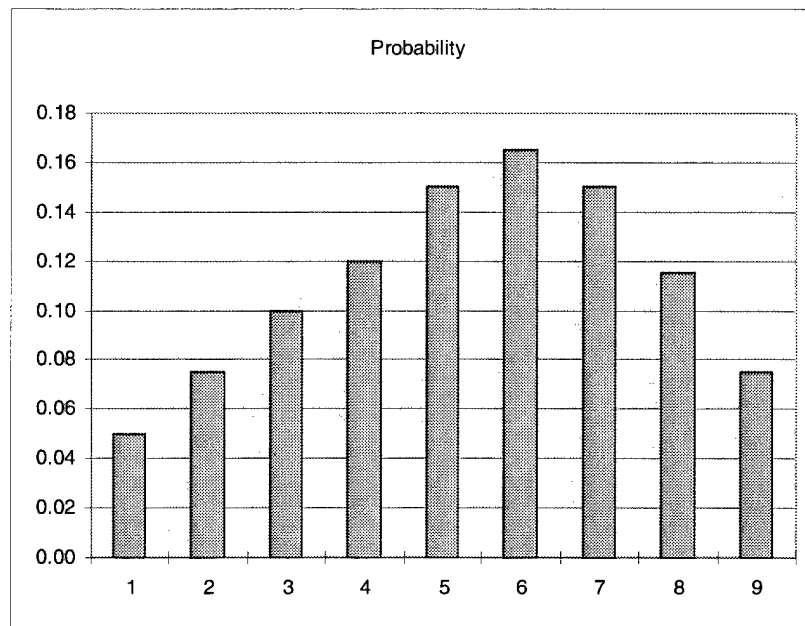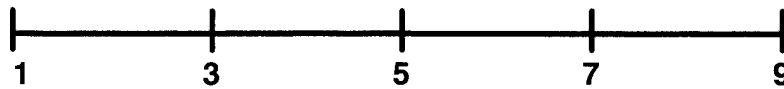
Comments:

◆ All options are considered likely—from batching to repair upon failure.

IV-5. Procurement of repair parts. How much flexibility will the source of repair have?

DoD materiel management system use is mandatory. (1)		Exceptions to the DoD system require approval. This exception process will, in fact, be used. (5)		SOR can determine best source, best value. (9)

```
|----------|----------|----------|----------|
1          3          5          7          9
```

Probability

```
0.25 |
     |  ▓
0.20 |  ▓                                    ▓
     |  ▓  ▓                                 ▓
0.15 |  ▓  ▓                          ▓     ▓
     |  ▓  ▓                          ▓     ▓
0.10 |  ▓  ▓                          ▓     ▓
     |  ▓  ▓  ▓                    ▓  ▓     ▓
0.05 |  ▓  ▓  ▓                    ▓  ▓     ▓
     |  ▓  ▓  ▓  ▓  ▓  ▓           ▓  ▓     ▓
0.00 |--1--2--3--4--5--6--7--8--9--
```
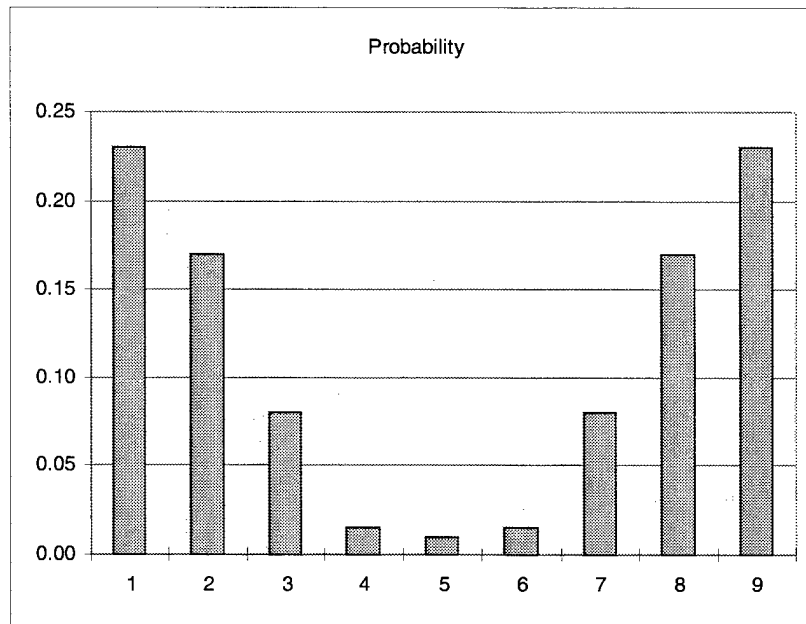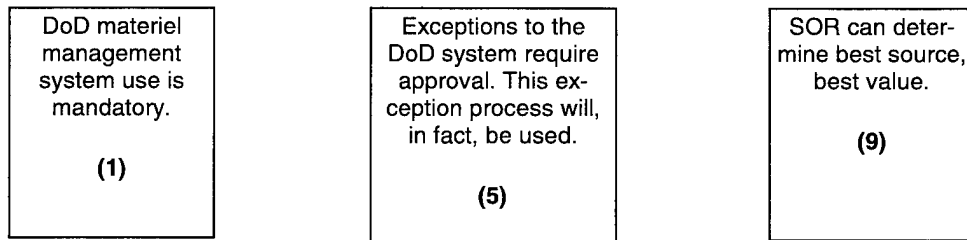
Comments:

◆ A bi-modal distribution of responses is expected.

➤ If the source of repair is an organic depot, extensive use of the DoD materiel management system is expected (although organic depots can request exceptions).

➤ If the source of repair is commercial, best source/best value could be the predominant procurement policy dependent on terms and conditions of the contract.

B-19

IV-6. Incentive structure.

| Provides limited incentive to improve cost and quality of product and service. May encourage SOR to serve own needs rather than those of customer.

 (1) | | Rewards and penalties tied only to repair cost.

 (5) | Provides rewards and penalties (e.g., profit, ability to keep business, accolades, and reprimands). Direct focus on cost and quality of product and service.

 (9) |

```
|——————————|——————————|——————————|——————————|
1          3          5          7          9
```

Probability

Value	Probability
1	0.00
2	0.01
3	0.05
4	0.11
5	0.18
6	0.24
7	0.18
8	0.13
9	0.10

Comments:

◆ All options except a 1 are possible.

◆ The mode is expected to be 6 because the majority of organic and commercial sources are expected to have incentive policies in place tied to factors beyond cost.

SECTION V: EVALUATION—NATURE OF SOURCES

V-1. What would be the availability of alternate sources of repair if this repair sector were selected?

Only one SOR will exist (e.g., the OEM or a single depot). **(1)**	There will be at least one alternate SOR. **(5)**	Many alternate SORs will exist. **(9)**

```
1        3        5        7        9
```

Probability - New System

Probability - Existing System

Comments:

◆ For new systems, viable responses are either 1 or 5 (only one source of repair or at least one alternate source of repair).

  ➤ If an OEM (without licensed repair stations) is likely, a 1 is anticipated.

  ➤ However, if the OEM has licensed repair stations or if an organic source of repair is chosen, at least one alternate source of repair will exist.

◆ For existing systems, a range of responses from 1 to 9 are equally possible.

V-2. Given this repair sector is chosen, what is the likelihood that a source of repair will have workload complementary to that for which the repair sector decision is being made?

| Will be a unique workload.

(1) | There will be complementary workload. Subject workload is anticipated to comprise approximately 50% of total complementary workload.

(5) | Work will be performed in an integrated facility. Subject workload is one of many that use complementary resources. This workload is less than 10% of total complementary workload.

(9) |

```
|———————|———————|———————|———————|
1       3       5       7       9
```

Probability

0.35								
0.30								
0.25								
0.20								
0.15								
0.10								
0.05								
0.00								
1	2	3	4	5	6	7	8	9
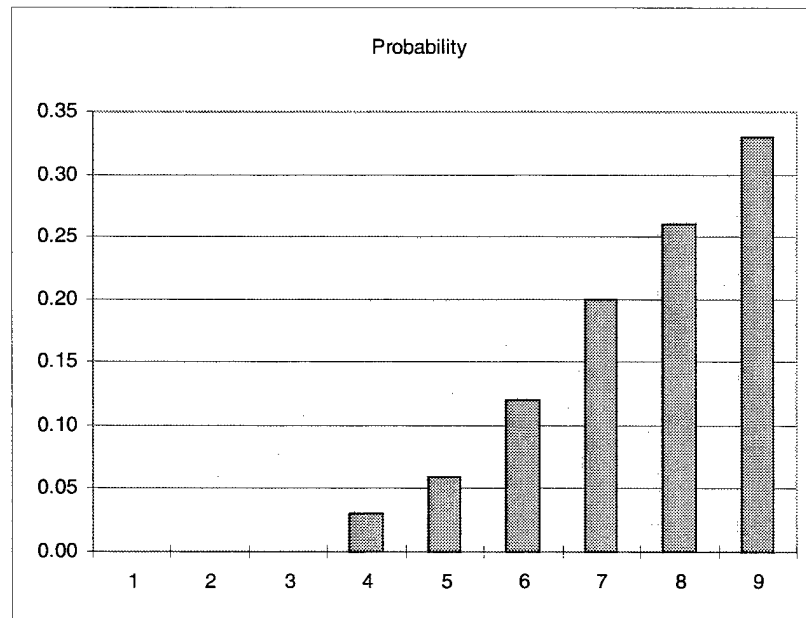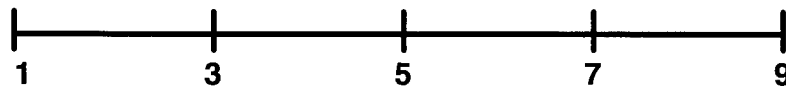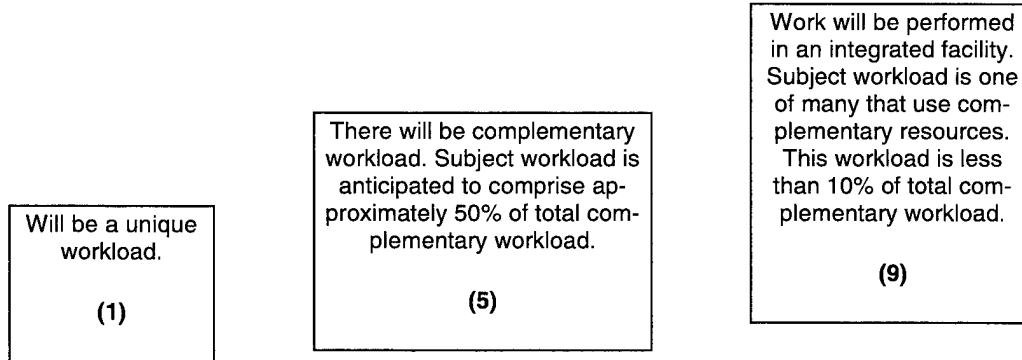
Comments:

◆ The DoD workload is assumed to be gas-turbine engine remanufacturing.

◆ It is unreasonable to expect the workload would be assigned to an SOR that does not currently accomplish gas-turbine remanufacturing (a 1 is therefore eliminated).

◆ The resulting scale is bounded on the left at 3 and continues up to 9 reflecting DoD's workload representing a range of over one-half to less than one-fourth of a source of repair's total propulsion workload.

V-3. Interest in this workload by potential sources.

| No interest.

(1) | | Two potential
SORs likely to
respond to a
request for
proposal or
similar
instrument.

(5) | | Five or more
potential
SORs likely to
respond to a
request for
proposal or
similar
instrument.

(9) |

```
 ├──────────┼──────────┼──────────┼──────────┤
 1          3          5          7          9
```

Probability - New System

	1	2	3	4	5	6	7	8	9
Probability					0.25	0.29	0.21	0.15	0.10

Probability - Existing System
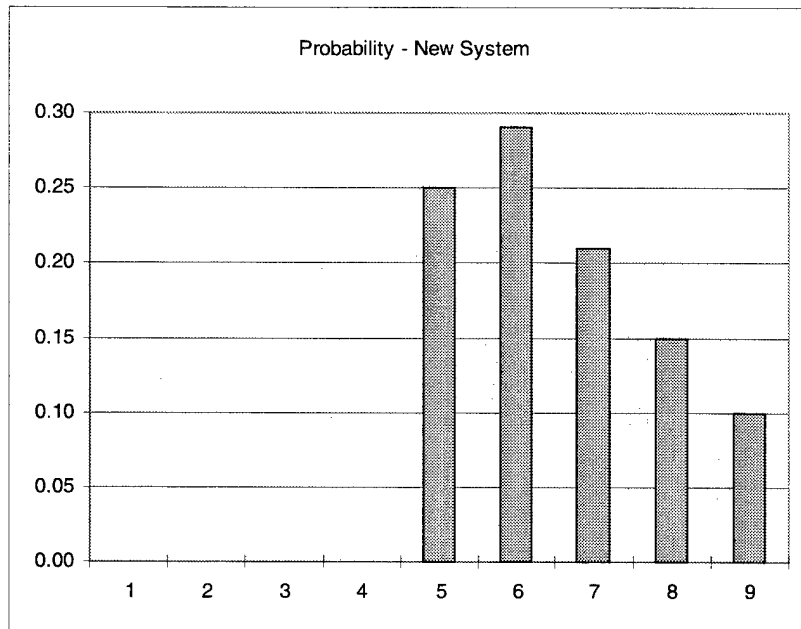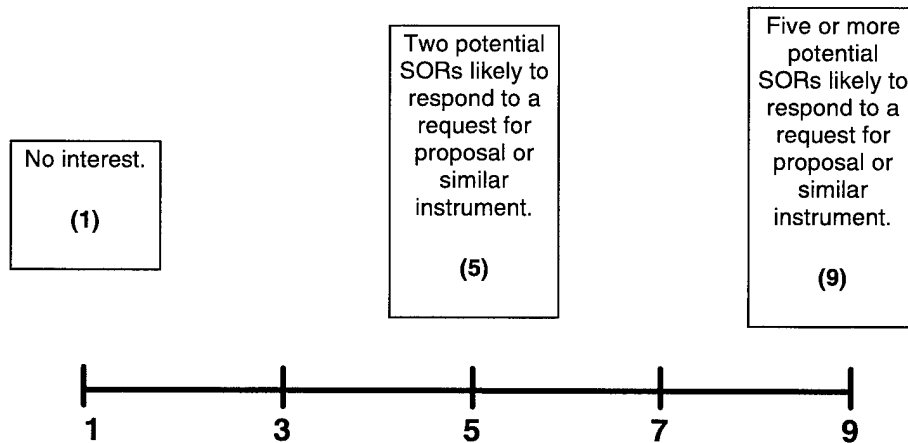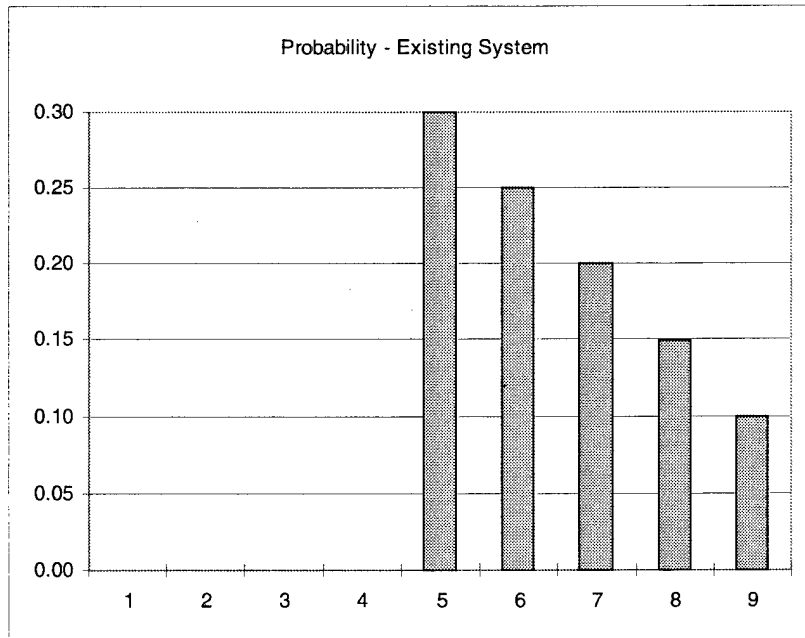
Comments:

◆ For new gas-turbine engines, at least two sources of repair would be expected—organic and the OEM. In addition, more than two SORs are possible if the OEM has licensed repair subsidiaries.

◆ For existing engines, an organic source of repair as well as the OEM are expected to be interested. In addition, additional potential sources would be available and would be expected to respond to a request for proposal or similar instrument.

V-4. Reserve capacity at a potential source of repair for this work.

No reserve capacity. **(1)**	Capacity is available to accomplish anticipated average peacetime (e.g., none-surge) workload. **(5)**	Capacity is available to accomplish highest postulated workload—including wartime, surge workload. **(9)**

```
|———————————|———————————|———————————|———————————|
1           3           5           7           9
```

Probability
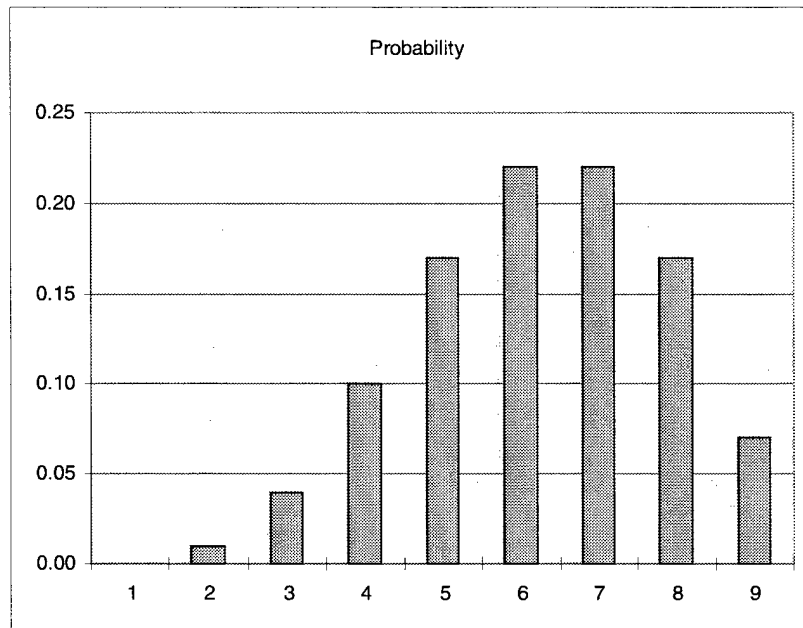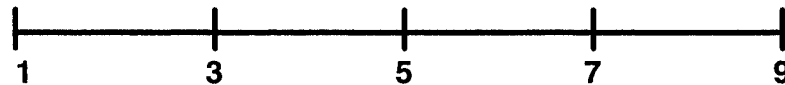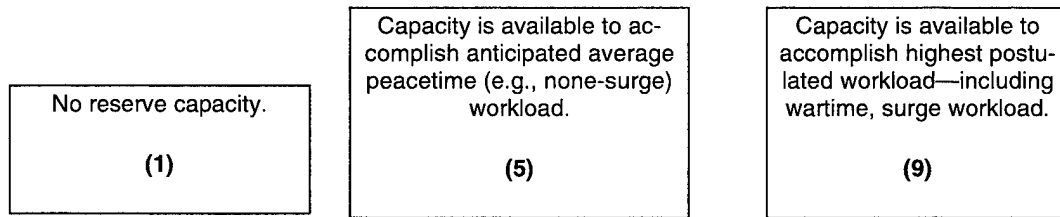
Comments:

◆ A "no reserve capacity" (1) is eliminated because it is not foreseen selecting a source of repair with no capacity to accomplish any of the projected remanufacturing workload.

◆ Alternatives 3 through 9 are possible; however, the greater likelihood is that a source of repair will be selected that has the reserve capacity above that required to accomplish the anticipated average peacetime workload (a mode of 6.5 has been established).

V-5. Typical source or repair's capacity in excess of workload.

SOR is burdened with large excess capacity that will take more than three years to shed. SOR total workload, including this workload, utilizes less than 70% of available capacity. **(1)**	SOR possesses some excess capacity. SOR total workload, including this workload, is approximately 80% of available capacity. **(5)**	No excess capacity above peak projected workload for an SOR. **(9)**

```
|————————|————————|————————|————————|
1        3        5        7        9
```

Probability

[Bar chart showing equal probability bars (~0.11) for ratings 1 through 9, with y-axis from 0.00 to 0.12]

Comments:

◆ All ratings are likely because of the wide variety of unique situations.

V-6. With respect to a typical SOR, what is the availability of labor with relevant basic skills?

| Will have to recruit and train required work force. (1) | Core of journeymen technicians in place. SOR must recruit and train additional personnel to accomplish this workload. (5) | Work force is at journeyman level. Quantities adequate for projected workload. (9) |

```
├──────────┼──────────┼──────────┼──────────┤
1          3          5          7          9
```

Probability

```
0.25 ┤
     │                    ┌─┐
0.20 ┤              ┌─┐   │ │   ┌─┐
     │              │ │   │ │   │ │
0.15 ┤              │ │   │ │   │ │
     │        ┌─┐   │ │   │ │   │ │   ┌─┐
0.10 ┤        │ │   │ │   │ │   │ │   │ │
     │        │ │   │ │   │ │   │ │   │ │
0.05 ┤  ┌─┐   │ │   │ │   │ │   │ │   │ │   ┌─┐
     │┌─┐│ │  │ │   │ │   │ │   │ │   │ │   │ │  ┌─┐
0.00 ┴┴─┴┴─┴──┴─┴───┴─┴───┴─┴───┴─┴───┴─┴───┴─┴──┴─┴
      1   2    3     4     5     6     7     8    9
```
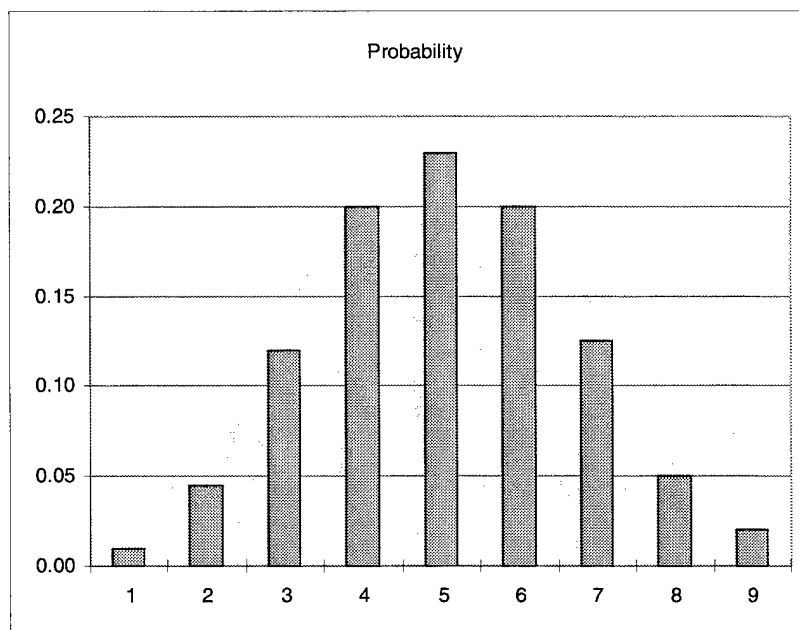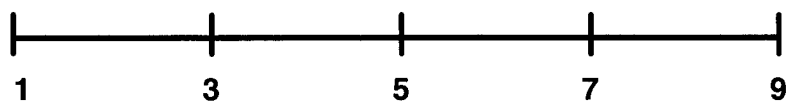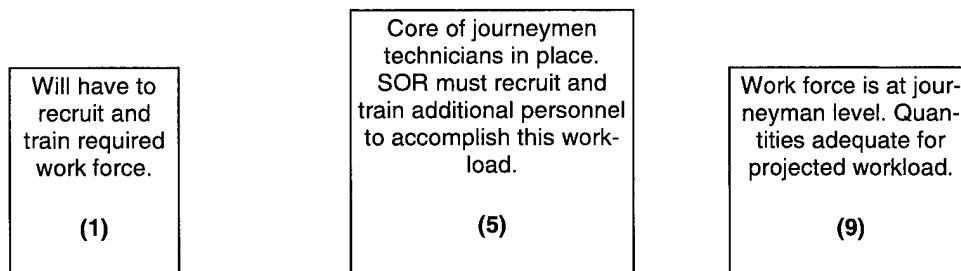
Comments:

◆ All ratings are possible; however, most sources would be concentrated around a 5 rating because they normally have a core of journeymen technicians in place.

V-7. Overhead structure at a potential source of repair.

| Overhead structure includes charges from engineering, manufacturing, and other activities in addition to remanufacturing/repair.

(1) | Overhead structure includes charges from engineering but not manufacturing.

(5) | Overhead structure tied to the specific requirements of the remanufacturing/repair workload.

(9) |

```
|———————|———————|———————|———————|
1       3       5       7       9
```

Probability

```
0.18 ┤
0.16 ┤                              ▓
0.14 ┤                        ▓     ▓
0.12 ┤              ▓         ▓     ▓
0.10 ┤              ▓   ▓     ▓     ▓   ▓
0.08 ┤        ▓     ▓   ▓     ▓     ▓   ▓
0.06 ┤  ▓  ▓  ▓     ▓   ▓     ▓     ▓   ▓   ▓
0.04 ┤  ▓  ▓  ▓     ▓   ▓     ▓     ▓   ▓   ▓
0.02 ┤  ▓  ▓  ▓     ▓   ▓     ▓     ▓   ▓   ▓
0.00 ┴──┴──┴──┴──┴──┴──┴──┴──┴──┴──┴──┴──┴──┴──
      1  2  3     4   5     6     7   8   9
```
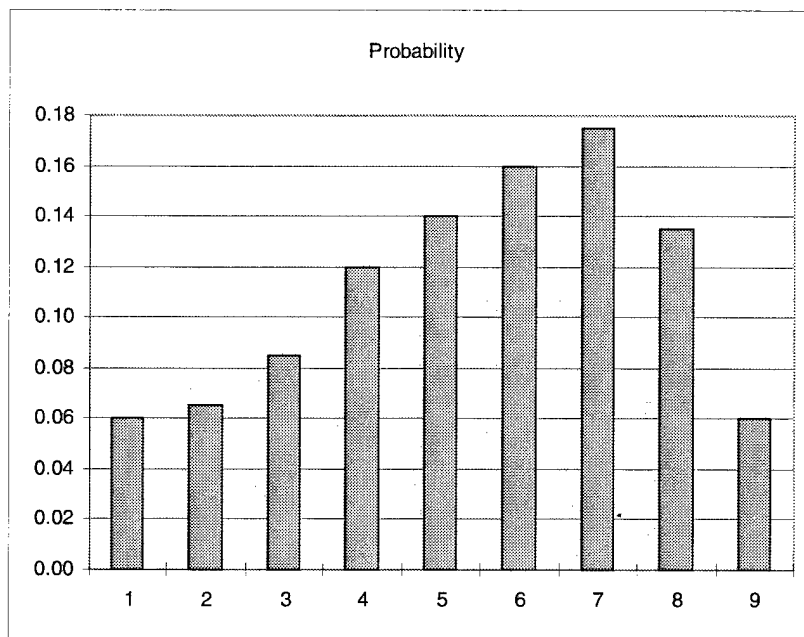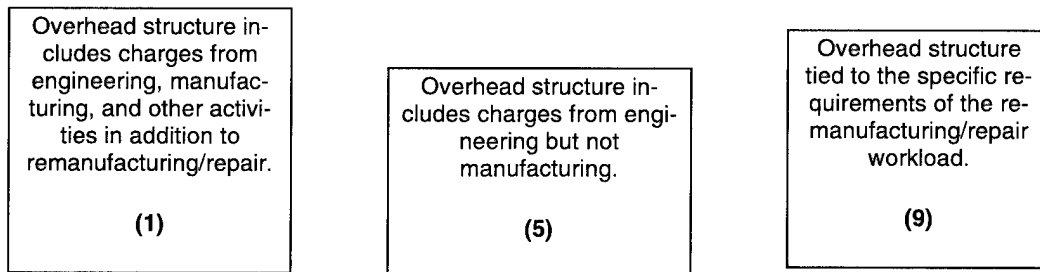
Comments:

◆ All ratings are possible.

◆ For propulsion remanufacturing, overhead would normally include some engineering activities.

V-8. Stability of labor relationships.
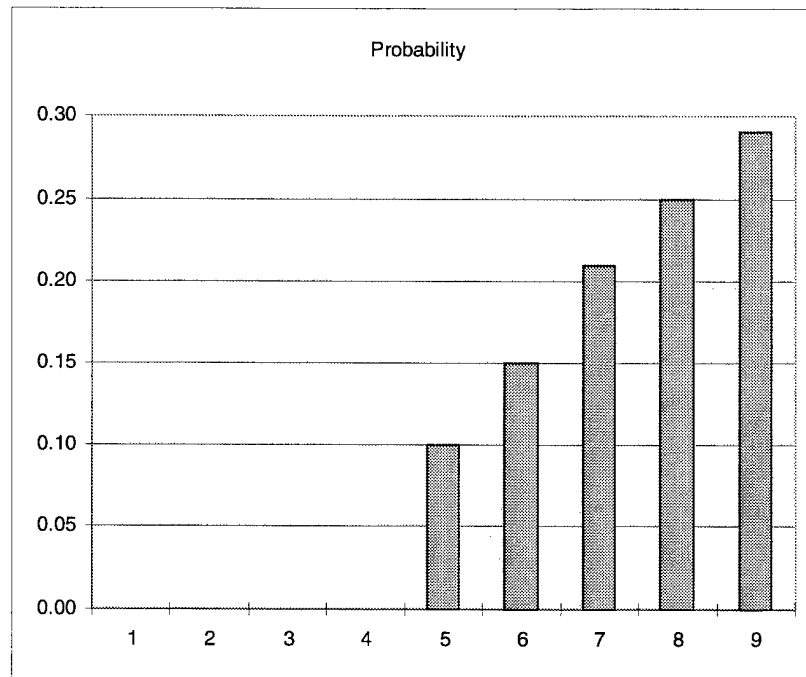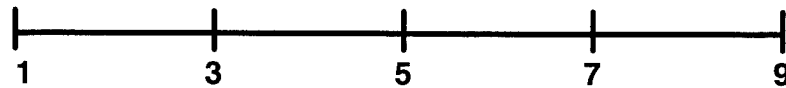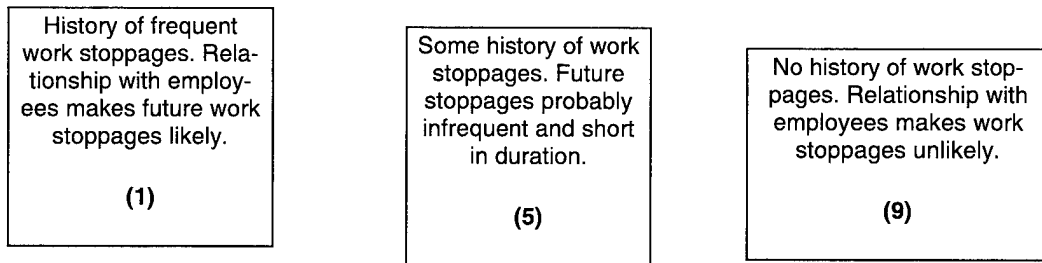
| History of frequent work stoppages. Relationship with employees makes future work stoppages likely. (1) | Some history of work stoppages. Future stoppages probably infrequent and short in duration. (5) | No history of work stoppages. Relationship with employees makes work stoppages unlikely. (9) |

```
├─────────┼─────────┼─────────┼─────────┤
1         3         5         7         9
```

Probability

Comments:

◆ It is not likely that DoD propulsion remanufacturing workload would be assigned to a source of repair that has an unstable labor relationship with its employees. Possible ratings of 1 and 3 are therefore eliminated.

◆ It is assumed that if the decision is organic, a very stable relationship would exist.

◆ It is assumed that if the decision is contract, a mix of stable and unstable labor relationships could exist.

V-9. Typical source of repair's knowledge of the customer (end user).
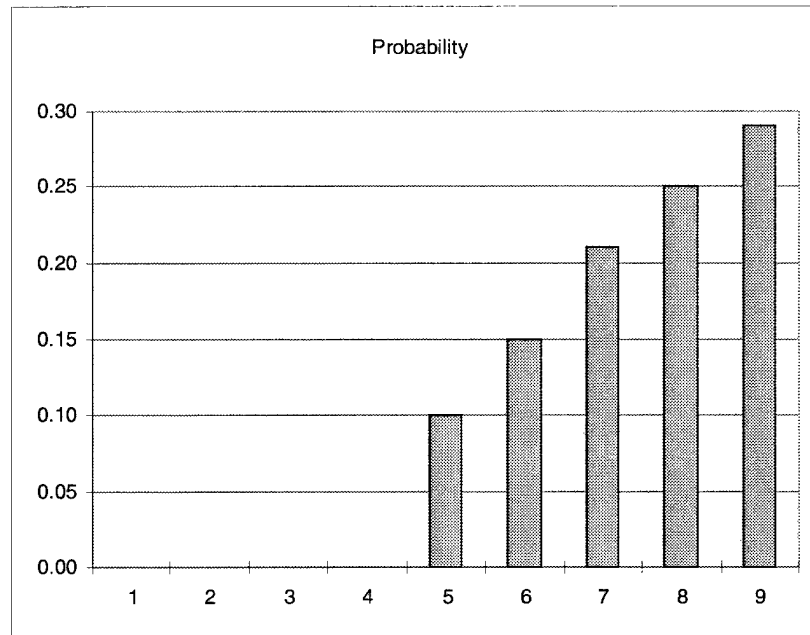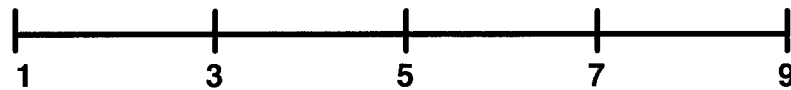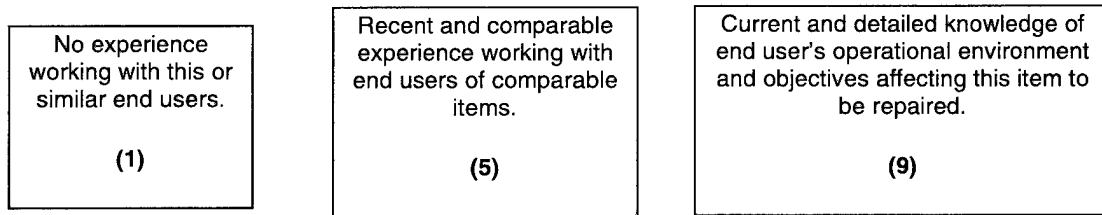
No experience working with this or similar end users. (1)	Recent and comparable experience working with end users of comparable items. (5)	Current and detailed knowledge of end user's operational environment and objectives affecting this item to be repaired. (9)

```
├───────────┼───────────┼───────────┼───────────┤
1           3           5           7           9
```

Probability

```
0.30 ┤                                              ▓▓
     │                                         ▓▓   ▓▓
0.25 ┤                                    ▓▓   ▓▓   ▓▓
     │                                    ▓▓   ▓▓   ▓▓
0.20 ┤                               ▓▓   ▓▓   ▓▓   ▓▓
     │                               ▓▓   ▓▓   ▓▓   ▓▓
0.15 ┤                          ▓▓   ▓▓   ▓▓   ▓▓   ▓▓
     │                          ▓▓   ▓▓   ▓▓   ▓▓   ▓▓
0.10 ┤                     ▓▓   ▓▓   ▓▓   ▓▓   ▓▓   ▓▓
     │                     ▓▓   ▓▓   ▓▓   ▓▓   ▓▓   ▓▓
0.05 ┤                     ▓▓   ▓▓   ▓▓   ▓▓   ▓▓   ▓▓
     │                     ▓▓   ▓▓   ▓▓   ▓▓   ▓▓   ▓▓
0.00 ┼────┬────┬────┬────┬────┬────┬────┬────┬────
      1    2    3    4    5    6    7    8    9
```

Comments:

◆ It is not likely that DoD propulsion remanufacturing workload would be assigned to a source of repair that has little or no experience working with the end user. Possible ratings of 1 and 3 are therefore eliminated.

◆ It is assumed that if the decision is organic, a high knowledge level of the end user's operational environment would exist.

◆ It is assumed that if the decision is contract, a variety of knowledge levels of the end user's operational environment would exist.

V-10. Typical source of repair's knowledge of the specific component(s) for which a repair sector decision is being made.

No knowledge of the item to be repaired and has no experience in similar technologies. **(1)**	Some knowledge of the item to be repaired and possesses experience with similar equipment and operating environments. **(5)**	Demonstrated knowledge of the item to be repaired, interface with the weapon system, and its operating environment. **(9)**

```
├──────────┼──────────┼──────────┼──────────┤
1          3          5          7          9
```

Probability - New System

Probability - Existing System

Rating	Probability
1	0.00
2	0.00
3	0.05
4	0.075
5	0.11
6	0.17
7	0.205
8	0.20
9	0.19
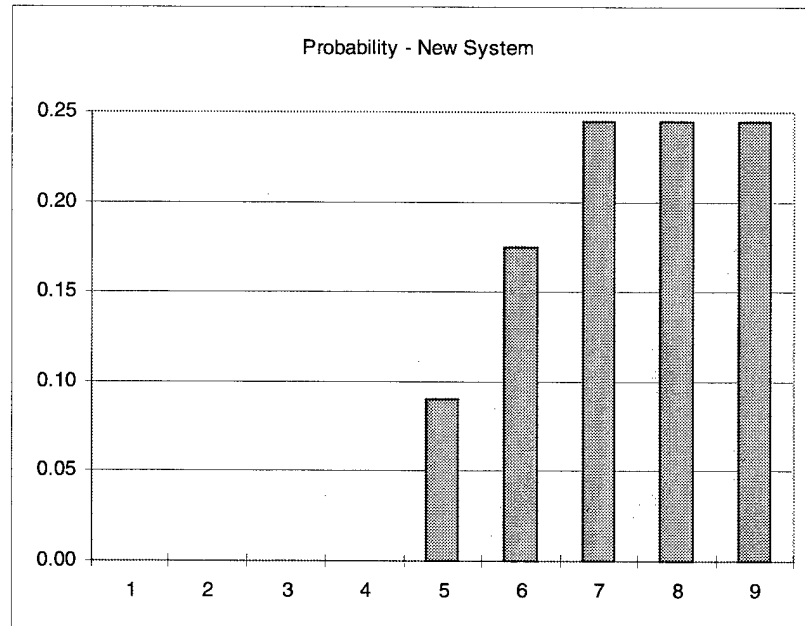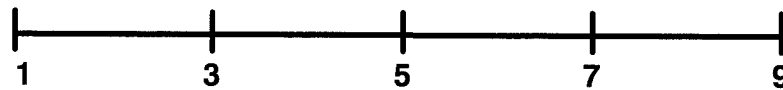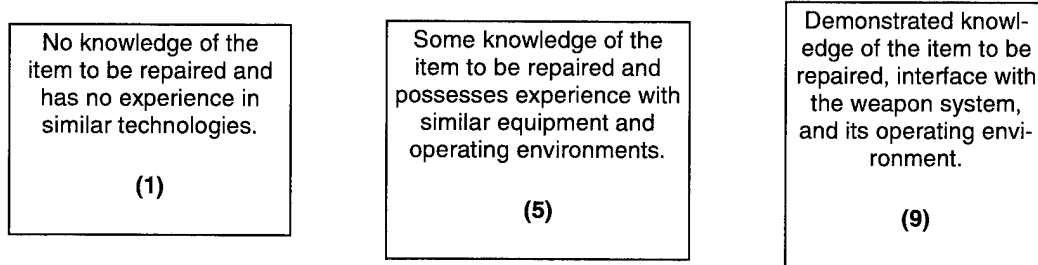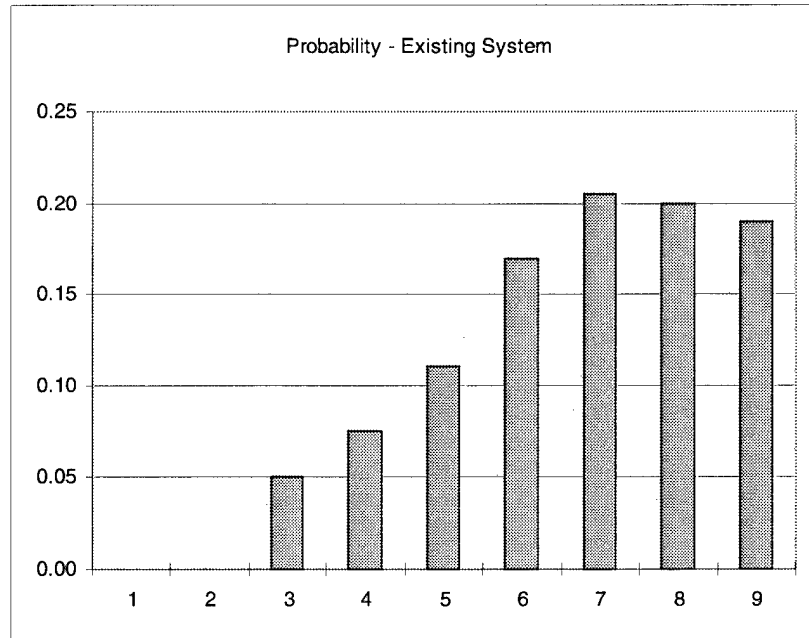
Comments:

◆ It is unlikely that a source of repair would be selected (for either a new or existing system) that has no knowledge of the item to be repaired. (A rating of 1 is therefore discounted.)

◆ For new propulsion systems, the ratings would be on the upper end of the scale reflecting the probability of workload assignment to an OEM or an existing organic propulsion remanufacturing facility that possesses knowledge of the engine (or similar engines) requiring repair.

◆ For existing engines, the curve would be expected to shift to the left reflecting the probability of an increased number of potential sources, some of which would not possess the degree of knowledge that the OEM and organic depots possess.

V-11. Source of repair's knowledge of the specific remanufacturing/repair process for which a repair sector decision is being made.

| No demonstrated experience with this or comparable processes. (1) | Demonstrated experience with comparable complexity processes. (5) | Demonstrated experience with required process and ability to optimize the process in specific applications. (9) |

```
├──────────┼──────────┼──────────┼──────────┤
1          3          5          7          9
```

Probability - New System

Value	1	2	3	4	5	6	7	8	9
Probability					0.15	0.21	0.28	0.21	0.15

Probability - Existing System
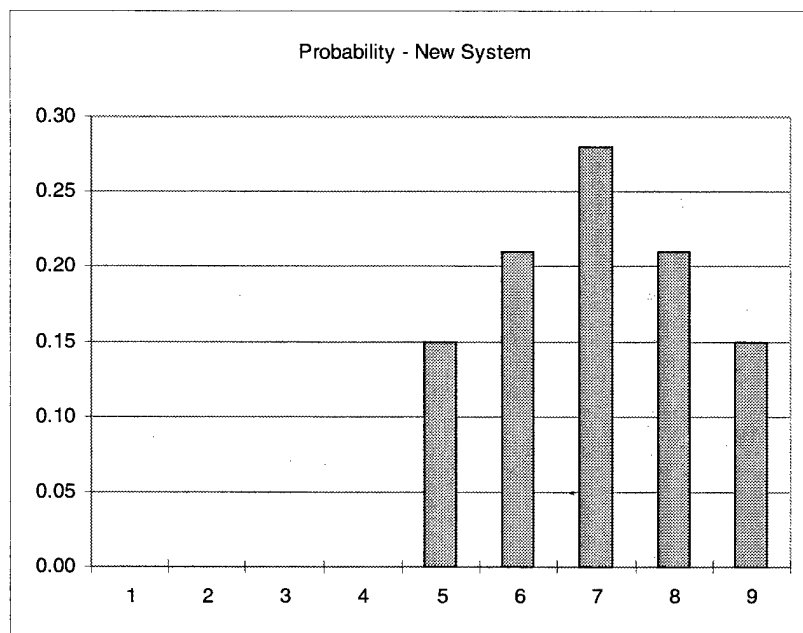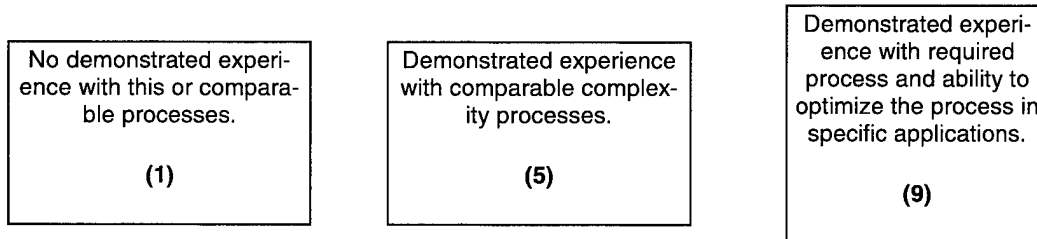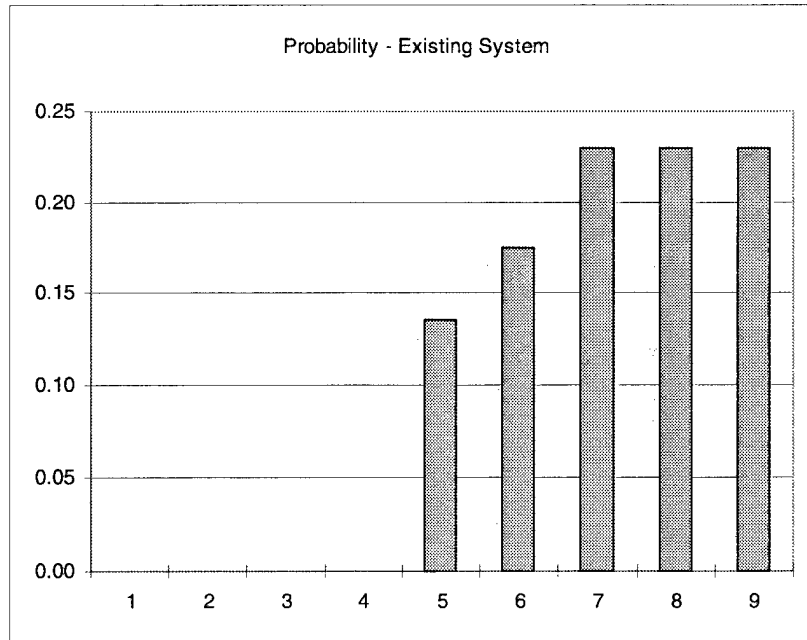
Comments:

◆ It is unlikely that a source of repair would be selected (for either a new or existing system) that has no knowledge of the remanufacturing/repair process. (Possible ratings of 1 and 3 are therefore discounted.)

◆ For new propulsion systems, the ratings would be on the upper end of the scale reflecting the high probability of workload assignment to an OEM or an existing organic propulsion remanufacturing facility.

◆ For existing propulsion systems, the ratings are similar because, in addition to the possibility of workload assignment to an OEM or an existing organic propulsion remanufacturing facility, third-party sources have had the opportunity to become familiar with the repair process.

V-12. Typical or anticipated source of repair's use of integrated manufacturing, engineering, financial planning and execution MRP-II management methods, and systems.

Pre-MRP-II methods and systems. (1)	MRP-II consistent methods and systems. (5)	Advanced with MRP-II/Enterprise Resource Planning (ERP) methods and systems. (9)

```
|———————|———————|———————|———————|
1       3       5       7       9
```
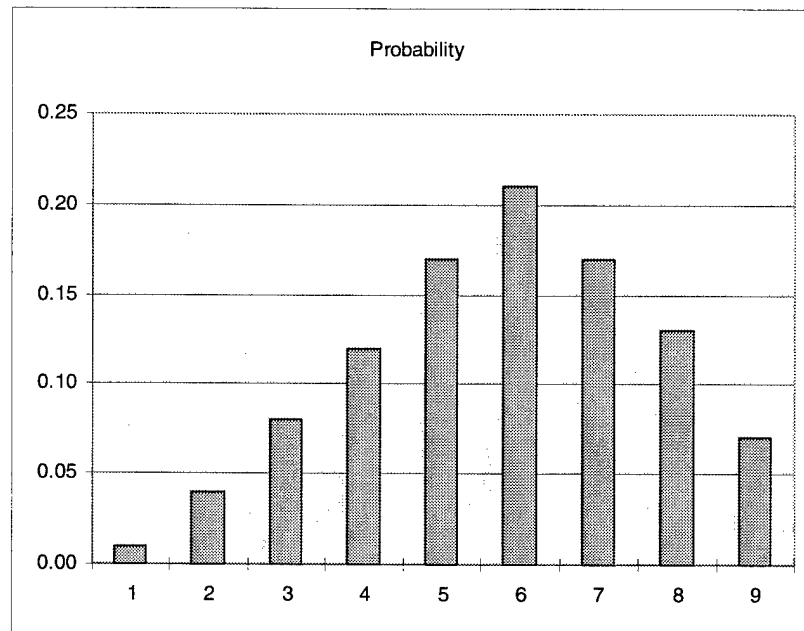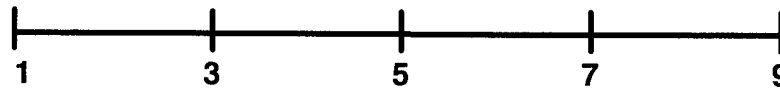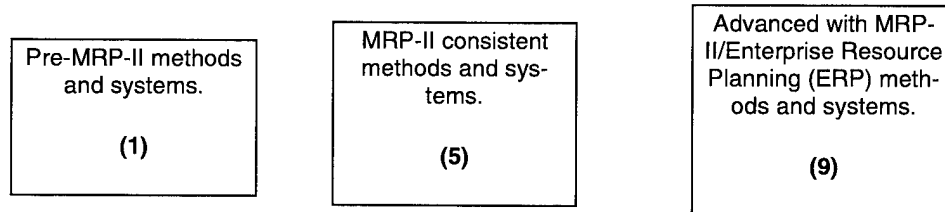

Probability

Comments:

◆ Based on the assumption that both organic and commercial sources are moving in the direction of institutionalizing MRP-II methods, a rating of 1 is not considered likely.

◆ Looking out at the next 3 to 7 years, the most likely probability would range between a 5 and 7, centered on a 6.

Appendix C
Trial Evaluation Workbook

Chapter 3 described the use of a workbook in support of integrated product/process teams as they evaluate repair sectors in terms of the factors described in Chapter 2. This appendix provides an example evaluation workbook. The workbook provided in this appendix was tailored for complex avionics workloads and is an updated version of the workbook used to assist in deciding which repair sector should support the V-22 forward looking infrared (FLIR) sub-system.

DEPOT MAINTENANCE REPAIR SECTOR SELECTION METHODOLOGY
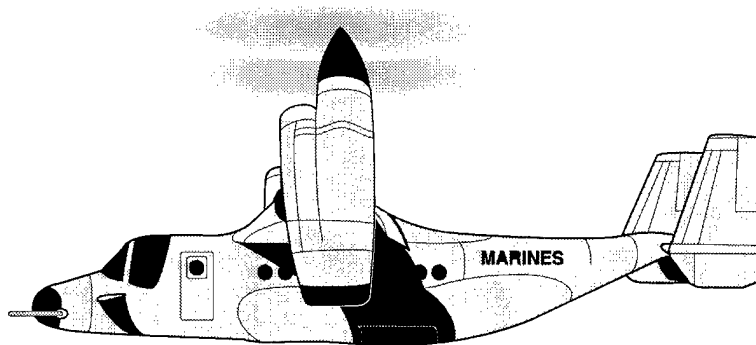
WORKBOOK

This Workbook is intended to assist in determining which repair
sector (public or commercial) is the best choice for repair of the
V-22 Forward Looking Infrared (FLIR) sub-system.
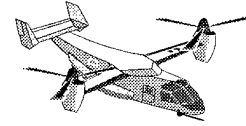
The selection of a repair sector is critical for each component or system. Obviously, it is
vital to select a repair sector that can satisfactorily accomplish the maintenance within
required time-frames, with required quality, and do so economically.

Selecting the "right" repair sector involves balancing characteristics of the system to be
maintained and prospective repair sectors against user needs. The method used to
attain this balance has been shown effective in industry for customer focused process
and product design and is called Quality Function Deployment (QFD). QFD is a system
for listening to the "voice of the customer" to bringing customers and providers together
through an intensive, interactive process.

The QFD process as applied here is shown graphically in figure 1. Customer inputs
(user needs) which provide the measure of "quality" in the process, are the
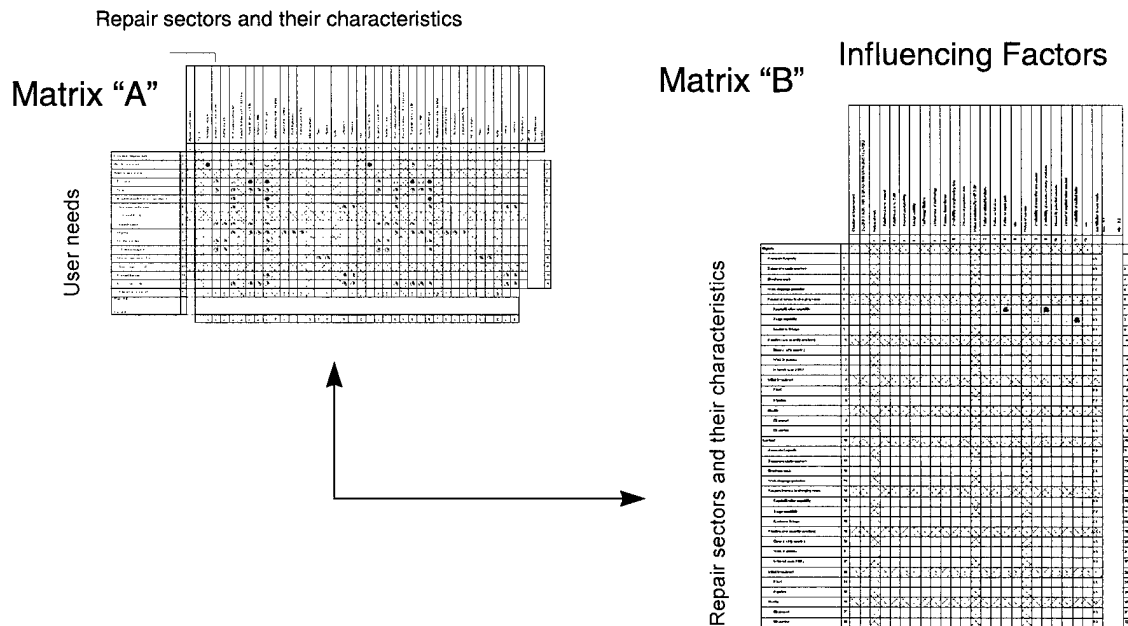
starting point for the QFD matrices. These prioritized operational customer needs
(responsiveness, low cost, etc.) are incorporated in Matrix A on the left side of figure 1.
Quality is "deployed" from one matrix to the other sequential manner (Matrix A to Matrix
B) as indicated by the arrow. The QFD matrices record the interrelationships between
needs, repair sector characteristics, and influencing factors as well as the "weights" or
strengths of these relationships. Lists of the repair sector characteristics and influencing
factors are provided in Sections I and II.

This Workbook assists logistics planners in rating each of the influencing factors in Matrix B on a scale of 1 to 9. The evaluation results will then be transferred to the QFD model and the model will do the mathematics to combine these evaluations with the operational needs input to complete the analysis. The influencing factors you will be evaluating in the Workbook are grouped in the following categories:

- Nature of the work to be performed
- Nature of relationship with sources of repair
- Nature of potential sources

Sections III, IV, and V form the heart of the workbook and are where you are requested to evaluate the Influencing Factors. Each factor is listed followed by a narrative description of a poor assessment, nominal assessment, and best assessment. A scale containing numerical values of 1, 3, 5, 7, and 9 is provided. You are requested to record the number that best characterizes each determining factor.

Your care and thoroughness in completing this workbook will be appreciated.

SECTION I
SOURCE OF REPAIR CHARACTERISTICS

ADEQUATE CAPABILITY & CAPACITY

SCOPE AND SCALE ECONOMY

OVERHEAD COSTS

NON-VALUE-ADDED EFFORT

EXTRAORDINARY PROFITS, FEES, EARNINGS

WORK STOPPAGE PROTECTION

RESPONSIVENESS TO CHANGING NEEDS
- Reprioritization Capability
- Surge Capability
- Task Flexibility
- Customer Linkage
- Administrative Ease

INCENTIVE TO IMPROVE

PIPELINE SIZE (QUANTITY AND TIME)
- Order and Ship (Administrative)
- Repair Cycle at SOR
- Material Movement (User-SOR-User)

OUTPUT QUALITY
- Of Product
- Of Service

SECTION II
INFLUENCING FACTORS

NATURE OF WORK TO BE PERFORMED
- Relative size (amount) compared to market place
- Relative size (amount) compared to SORs total workload
- Demand predictability
- Design stability
- Technology renewal rate
- Uniqueness of technology
- Repair process dependence
- Availability of engineering data
- Absence of proprietary data

NATURE OF RELATIONSHIP WITH SORs
- Ability to change requirements
- Scope of relationship
- SOR's responsibility for related functions (e.g., engineering)
- Policy on reparable lot sizes
- Policy on procurement of repair parts
- Incentive structure

NATURE OF SOURCES
- Availability of more than one qualified source
- Availability of sources with complementary workload
- Interest by potential sources
- Reserve capacity for this work
- Capacity in excess of workload
- Availability of skilled labor
- Overhead structure
- Stability of SOR's labor relationship
- Customer knowledge
- Product knowledge
- Process knowledge
- MRP-II consistent management methods

Evaluation Factor: III-1.

Relative size (amount) of this workload compared to total market. Includes organic and private sector market places.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◒	◔				◒		◔	
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	

Evaluation:

This workload is the total market. No other similar workload exists anywhere. **(1)**

Total market includes other similar work which may be partially commercial. This workload is the driver - greater than 75%. **(3)**

Total market includes other similar work with this workload approximately equal to commercial work. **(5)**

This workload is in the commercial mainstream. Absence or presence of this workload would have no significant effect on the market. **(9)**

```
1       2       3       4       5       6       7       8       9
Poor Assessment                 Nominal                         Best Assessment
                                Assessment
```

Enter contract & organic score in this block

Comments:

Evaluation Factor: III-2.

Relative size (amount) of this workload compared to typical commercial or organic source of repair's total workload.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
●	●					◕		◕

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
◓								

Evaluation:

This would be the only workload. (1)		This is approximately one-half of the workload. (5)		This represents less than one-fourth of the workload. (9)

```
1        2        3        4        5        6        7        8        9
Poor                              Nominal                          Best
Assessment                        Assessment                       Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: III-3.

Demand predictability[1].

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	◗							
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	
				●				

Evaluation:

Forecasting of little or no avail. The peaks and valleys of workload are extreme. The best plan is flexibility to react.
(1)

Forecasting of some use. Workload will vary from calendar quarter to quarter.
(5)

Has peaks and valleys but amount of workload consistent from one calendar quarter to another.
(7)

No surprises. Forecast workload and actual workload are essentially identical (e.g., time change items).
(9)

```
  1       2       3       4       5       6       7       8       9
Poor Assessment                 Nominal                      Best Assessment
                                Assessment
```

Enter contract & organic score in this block | |

Comments:

[1] Evidence is that most avionics would rate a "1" on the above scale because predictability of demand for modern avionics is poor in general. This means that in order for a source of repair to see a reasonably steady workload, a relatively large number of complimentary units (i.e., units that use essentially the same repair process) need to be "pooled." The problem is less severe with mechanical components.

Evaluation Factor: III-4.

Design stability. Changes resulting from functional enhancements, reliability improvements, etc., that affect the repair process (e.g., change form, fit, or function). Excludes design changes that do not affect the repair process.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	●							
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	
			◕	◒	◕			

Evaluation:

| Design evolving, changes affecting the repair process a certainty. (1) | | | | Some possibility of changes that affect the repair process. (5) | | | | No changes envisioned that affect the repair process. (9) |

```
  1        2        3        4        5        6        7        8        9
Poor Assessment                           Nominal                    Best Assessment
                                        Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: III-5.

Technology renewal rate. How often does one generation of technology replace another?

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
	◕		◔	◔	◔	◒		

Evaluation:

Greater than 10 years. (1)				About 5 years. (5)				Less than 3 years. (9)

```
1        2        3        4        5        6        7        8        9
Poor Assessment                  Nominal                        Best Assessment
                                 Assessment
```

Enter contract & organic score in this block

Comments:

Evaluation Factor: III-6.

Uniqueness of technology.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◒	●					◒	◵	◴
Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	

Evaluation:

| Unique MIL technology with few other applications. **(1)** | | | | Primarily MIL but many different MIL applications. **(5)** | | | | In mainstream. Many applications beyond military. **(9)** |

```
|----+----+----+----+----+----+----+----|
1    2    3    4    5    6    7    8    9
Poor Assessment              Nominal              Best
                            Assessment           Assessment
```

Enter contract & organic score in this block | |

Comments:

Evaluation Factor: III-7.

Repair process dependence. (Repair process includes skills, training, data, equipment, environment, facilities, etc.)

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◑	●					◔	◔	◔

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
				◕				

Evaluation Scoring:

Repair is dominated by unique repair processes applicable only to this workload.
(1)

Requires some unique processes.
(5)

Uses common, widely available processes.
(9)

```
   1       2       3       4       5       6       7       8       9
 Poor                         Nominal                         Best
Assessment                   Assessment                    Assessment
```

Enter contract & organic score in this block | |

Comments:

Evaluation Factor: III-8.

Availability of engineering data to design the repair process. Does it exist?

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◑	◕							
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	
						◔	◔	

Evaluation:

| Reverse engineering required to develop and maintain repair capability. (1) | | | | Reverse engineering required to augment available data. (5) | | | | Adequate data available to develop and maintain repair process without reverse engineering. (9) |

```
  1       2       3       4       5       6       7       8       9
Poor Assessment                        Nominal                        Best Assessment
                                       Assessment
```

Enter contract & organic score in this block | |

Comments:

Evaluation Factor: III-9.

Absence of proprietary data that affects the design of repair process.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
●	◕							

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
	◔	◕						

Evaluation:

Proprietary data is required. OEM (or subcontractor to OEM) will not release proprietary data to this source under acceptable terms.
(1)

Proprietary data required - OEM (or subcontractor to OEM) will negotiate rights with this source.
(5)

No proprietary data impacts.
(9)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

Poor Assessment

Nominal Assessment

Best Assessment

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: IV-1.

Ability to change requirements. Depends upon the flexibility of the relationship between buyer of repair services and source of repair[1].

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
		◕				●	●	●

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
◓	◔	●	◕	◷	◷	◔	◔	

Evaluation:

Changing what, how many or when is difficult and time consuming (typical of firm fixed price contract). (1)	Changing what, how many or when requires an acceptable amount of time and expenditure of resources (typical of basic ordering agreement or quarterly workload negotiations). (5)	Changing what, how many, or when is easy and quick (typical of arrangements that have equal sharing of risks and benefits). (9)

```
     1        2        3        4        5        6        7        8        9
Poor Assessment                      Nominal                       Best Assessment
                                    Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

[1] Basis of relationship may be formal or informal e.g., firm fixed price contract, basic ordering agreement (BOA), memorandum of agreement (MOA), organic production schedule, etc.

Evaluation Factor: IV-2.

Scope of relationship[1]. What is the intended work package (how many reparable items[2] are in the work package that use complementary repair processes and resources)?

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	●					◑		◑

| Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
	◒	◒						

Evaluation:

Only one reparable item is included in work package. (1)	Two or three reparable items are included in work package. (3)	Between four and eight reparable items are included in the work package. (5)	Between nine and nineteen reparable items are included in the work package. (7)	Twenty or more reparable items are included in the work package. (9)

```
1       2       3       4       5       6       7       8       9
Poor Assessment                 Nominal                         Best Assessment
                                Assessment
```

Enter contract & organic score in this block [   ]

Comments:

[1] The scope of relationship is important to workload leveling. The broader the scope, the more peaks and valleys from individual components will level each other out. Complementary processes and resources use similar (or the same) skills, similar (or the same) equipment, similar (or the same) task sequences, etc. Scope can be either vertical (many components from the same system) or horizontal (similar components from many systems).

[2] Examples of reparable items include actuators, engine components, avionics components, landing gears, and transmission assemblies.

Evaluation Factor: IV-3.

Source of repair's direct responsibility for: materiel management, sustaining engineering, distribution and transportation.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
								◑
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	
◕	◔		◕		◕		◑	

Evaluation:

Responsibility limited to repair. The SOR has no responsibility for non-repair functions. (1)				Responsibility includes repair and some of the four related functions. (5)				Responsibility includes repair and all four related functions. (9)

```
1      2      3      4      5      6      7      8      9
Poor Assessment                Nominal                        Best Assessment
                              Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: IV-4.

Policy on reparable lot sizes. What lot sizes will be presented to the source of repair?

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	●					◓		

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
		◔	◓	●		◔		

Evaluation:

Workload accumulates. Nothing is released to repair process until some preset quantity of reparables are on hand (1)				Monthly induction where the quantity inducted is based on user needs. (5)				Every individual failure in the field triggers an immediate repair response. (9)

```
  1       2       3       4       5       6       7       8       9
Poor Assessment                     Nominal                        Best Assessment
                                    Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: IV-5.

Procurement of repair parts. How much flexibility will the source of repair have?

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	◕				◕	●	◔	◔

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
	◔	◒		●		◕		

Evaluation:

DoD material management system use in mandatory. (1)		Exceptions to the DoD system require approval. This exception process will, in fact, be used. (5)			SOR can determine best source, best value. (9)

```
├──┼──┼──┼──┼──┼──┼──┼──┤
1  2  3  4  5  6  7  8  9
```

Poor Assessment   Nominal Assessment   Best Assessment

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation factor: IV-6.

Incentive structure.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◕		◑	◑	◐	◕	◕	◕	◕

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
◐	●	◕	◑	●	◕	◕	◕	

Evaluation:

| Provides limited incentive to improve cost and quality of product and service. May encourage SOR to serve own needs rather than those of customer. **(1)** | | | | Rewards and penalties tied only to repair cost. **(5)** | | | | Provides rewards and penalties (e.g., profit, ability to keep business, accolades and reprimands). Direct focus on cost and quality of product and service **(9)** |

```
   1      2      3      4      5      6      7      8      9
Poor                        Nominal                 Best Assessment
Assessment                  Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-1.

What would be the availability of alternate sources of repair if this repair sector were selected?

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◑		◑	◑	●	◕		◔	◔

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
◕	◕					◕	◕	

Evaluation:

Only one SOR will exist (e.g., the OEM or a single depot). (1)

There will be at least one alternate SOR. (5)

Many alternate SORs will exist. (9)

```
1       2       3       4       5       6       7       8       9
Poor Assessment                  Nominal                    Best Assessment
                                 Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-2.

Given this repair sector is chosen, what is the likelihood that a typical source of repair will have workload complementary to that for which the repair sector decision is being made?[1]

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	●	◔			◒	●		
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	
		◒				◕		

Evaluation:

Will be unique workload. **(1)**

There will be complementary workload. Subject workload is anticipated to comprise approximately 50% of total complementary workload. **(5)**

Work will be performed in an integrated facility. Subject workload is one of many that use complementary resources. This workload is less than 10% of total complementary workload. **(9)**

```
|-----|-----|-----|-----|-----|-----|-----|-----|
1     2     3     4     5     6     7     8     9
Poor Assessment           Nominal                    Best Assessment
                          Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

[1] Complementary workload is important to workload leveling. The greater the amount of complementary workload, the more peaks and valleys from individual components will level each other out. Complementary processes and resources use similar (or the same) skills, similar (or the same) equipment, similar (or the same) task sequences, etc. Complementary workload can be either vertical (many components from the same system) or horizontal (similar components from many systems).

Evaluation Factor: V-3.

Interest in this workload by potential sources.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◑		◕	◕	◕	◔			◔
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	
◑	◔					◔	◔	

Evaluation:

| | | | | Two potential SORs likely to respond to a RFP or similar instrument. **(5)** | | | | Five or more potential SORs likely to respond to a RFP or similar instrument. **(9)** |

No interest.
(1)

```
1       2       3       4       5       6       7       8       9
Poor Assessment                 Nominal                         Best Assessment
                                Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-4.

Reserve capacity at a potential source of repair for this work.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
●						●	●	
Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	

Evaluation:

No reserve capacity.
(1)

Capacity is available to accomplish anticipated average peacetime (e.g., non-surge) workload
(5)

Capacity is available to accomplish highest postulated workload - including wartime, surge workload.
(9)

```
  1     2     3     4     5     6     7     8     9
Poor Assessment              Nominal                 Best Assessment
                             Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-5.

Typical source of repair's capacity in excess of workload.
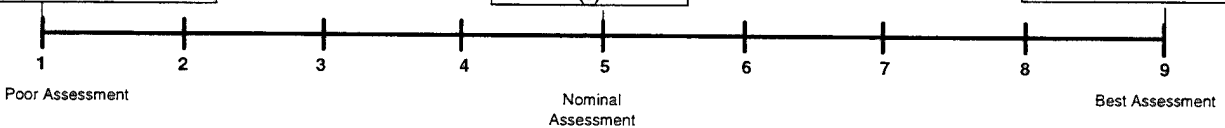
This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
		●	◒					

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
	◕			◔				

Evaluation:

SOR is burdened with large excess capacity which will take more than three years to shed. SOR total workload, including this workload, utilizes less than 70% of available capacity.
(1)

SOR possesses some excess capacity. SOR total workload, including this workload, is approximately 80% of available capacity.
(5)

No excess capacity above peak projected workload for this SOR.
(9)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

Poor Assessment   Nominal Assessment   Best Assessment

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-6.

With respect to a typical source of repair, what is the availability of labor with relevant basic skills?
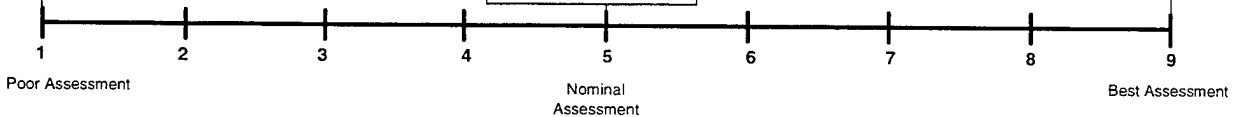
This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
●		◕	◑			◑	●	◑

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
				◕		◕	◑	

Evaluation:

Will have to recruit and train required workforce.
(1)

Core of journeymen technicians in place. SOR must recruit and train additional personnel to accomplish this workload.
(5)

Workforce is at journeyman level. Quantities adequate for projected workload.
(9)

1   2   3   4   5   6   7   8   9

Poor Assessment   Nominal Assessment   Best Assessment

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-7.

Overhead structure at a potential source of repair.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
		●						
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	

Evaluation:

Overhead structure includes charges from engineering, manufacturing and other activities in addition to remanufacturing/repair.
(1)

Overhead structure includes charges from engineering but not manufacturing.
(5)

Overhead structure tied to the specific requirements of the remanufacturing/repair workload.
(9)

```
1       2       3       4       5       6       7       8       9
```

Poor Assessment

Nominal Assessment

Best Assessment

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-8.
Stability of labor relationships.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
		◔			◕			
Responsiveness to changing needs: Customer linkage	**Incentive to improve**	**Administrative ease**	**Pipeline size Order and ship (admin.)**	**Pipeline size Repair cycle at SOR**	**Pipeline size Material movement (user-SOR-user)**	**Output quality of product**	**Output quality of services**	
				◔		◔	◔	

Evaluation:

History of frequent work stoppages. Relationship with employees makes future work stoppages likely.
(1)

Some history of work stoppages. Future stoppages probably infrequent and short in duration.
(5)

No history of work stoppages. Relationship with employees makes work stoppages unlikely.
(9)

```
1       2       3       4       5       6       7       8       9
```
Poor Assessment   Nominal   Best Assessment
                                   Assessment

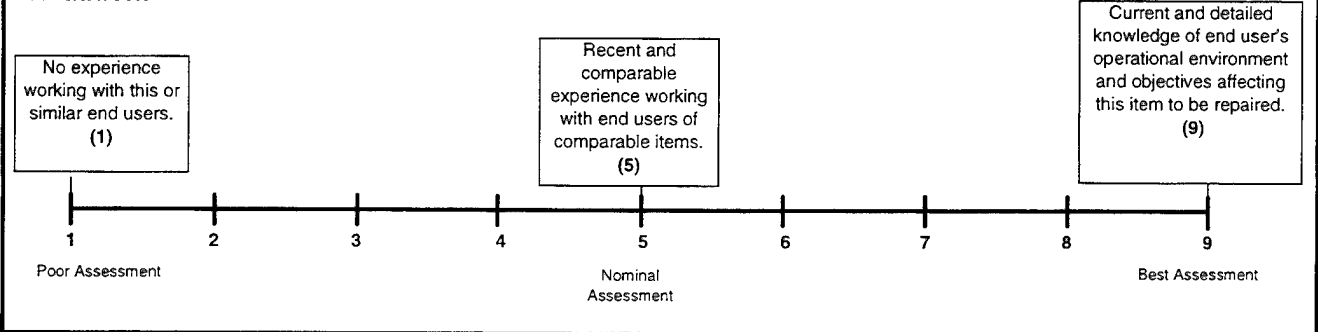| **Enter contract score in this block**	
Enter organic score in this block	

Comments:

C-31

Evaluation Factor: V-9.
Typical source or repair's knowledge of the customer (end user).

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	◔		◕			◒	◒	◔

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
●	◒	◔				●	●	

Evaluation:

No experience working with this or similar end users.
(1)

Recent and comparable experience working with end users of comparable items.
(5)

Current and detailed knowledge of end user's operational environment and objectives affecting this item to be repaired.
(9)

```
1       2       3       4       5       6       7       8       9
Poor Assessment                   Nominal                         Best Assessment
                                  Assessment
```

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-10.

Typical source of repair's knowledge of the specific component(s) for which a repair sector decision is being made.
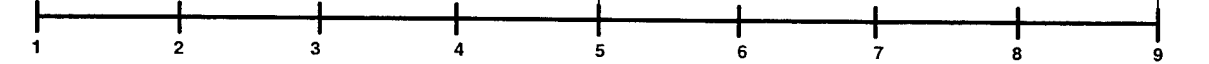
This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◒	◕		◔					◒

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
◒						◕	◒	

Evaluation:

No knowledge of the item to be repaired and has no experience in similar technologies.
(1)

Some knowledge of the item to be repaired and possesses experience with similar equipment and operating environments.
(5)

Demonstrated knowledge of the item to be repaired, interface with the weapon system and its operating environment.
(9)

```
1     2     3     4     5     6     7     8     9
```

Poor Assessment

Nominal Assessment

Best Assessment

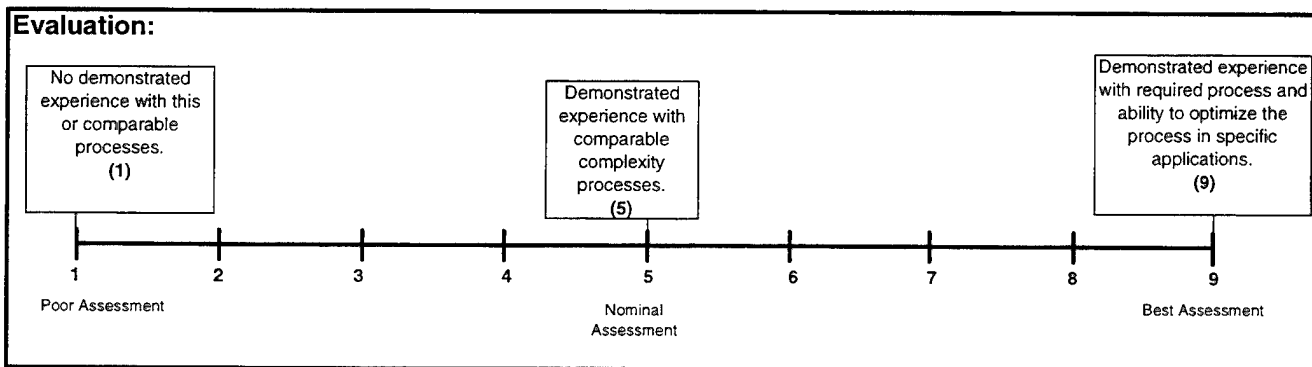| Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-11.

Source of repair's knowledge of the specific remanufacturing/repair process for which a repair sector decision is being made.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
◕	◕		◓			◕	◕	◓

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
				●		●	◕	

Evaluation:

No demonstrated experience with this or comparable processes.
(1)

Demonstrated experience with comparable complexity processes.
(5)

Demonstrated experience with required process and ability to optimize the process in specific applications.
(9)

1   2   3   4   5   6   7   8   9

Poor Assessment

Nominal Assessment

Best Assessment

Enter contract score in this block	
Enter organic score in this block	

Comments:

Evaluation Factor: V-12.

Typical source of repair's use of integrated manufacturing, engineering, financial planning and execution [Manufacturing Resources Planning (MRP-II)] management methods and systems.

This factor affects:

Adequate Capacity and Capability	Scope & scale economy	Overhead costs	Non-value-added effort	Extraordinary profits, fees, earnings	Work stoppage protection	Responsiveness to changing needs: Reprioritization capability	Responsiveness to changing needs: Surge capability	Responsiveness to changing needs: Task flexibility
	◕		●			◕	◔	

Responsiveness to changing needs: Customer linkage	Incentive to improve	Administrative ease	Pipeline size Order and ship (admin.)	Pipeline size Repair cycle at SOR	Pipeline size Material movement (user-SOR-user)	Output quality of product	Output quality of services	
◕		◕	◔	●		◔	◔	

Evaluation:

Pre MRP methods and systems.[1]
(1)

MRP consistent methods and systems.[2]
(5)

Advanced with MRP-II/Enterprise Resource Planning (ERP) methods and systems.[3]
(9)

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|----|----|----|----|----|----|----|----|
1    2    3    4    5    6    7    8    9
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Poor Assessment   Nominal   Best Assessment
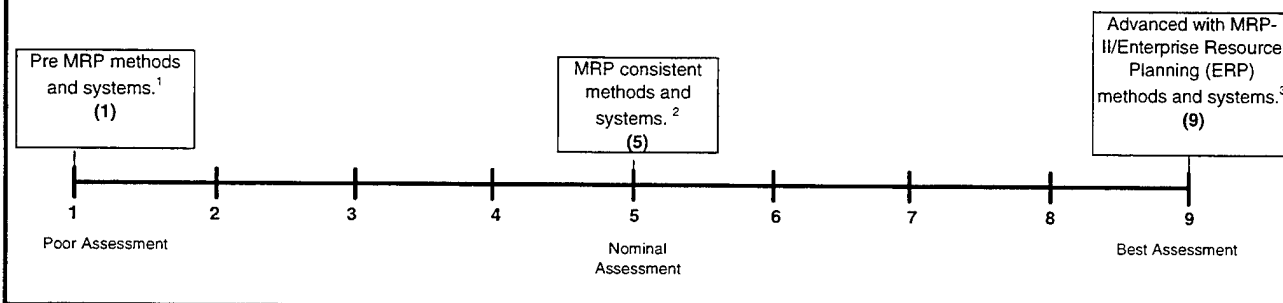   Assessment

Enter contract score in this block	
Enter organic score in this block	

Comments:

[1] Production/remanufacturing resource planning processes are based on historical usage and/or one time buys for items. Purchasing and manufacturing orders of individual parts and assemblies occur when predetermined order points are reached or parts are simply ordered as a need is identified. Automated support may exist, but it does not support time-phased acquisition and assembly of components, subassemblies and/or end items with closed loop feedback between remanufacturing, finance, and customers.

[2] Production/remanufacturing resource planning system (homegrown or commercial planning system) supports multi-level bills of material & routers construction for the generation of time-phased purchasing and production requirements from a master production schedule (MPS). The MPS is input into a material requirements or finite scheduling planning processor. The output of the production/manufacturing resources planning system is used to assess capacity, plan & control material orders, shop orders, and to provide exception messages which require follow-up and correction. The automated planning system only partially supports the management of the business and does not fully support a closed loop feedback among remanufacturing, engineering, finance and customers.

[3] Production/remanufacturing resource planning system is a closed loop system, providing planning, control and measurement support for the management of the entire business enterprise. Inventory bills of material and routers accuracy are at least 95% or better. It provides near real time feedback on execution versus the plan and inventory status to finance, customer interface/marketing, and remanufacturing operations. The automated information system includes interfaces and integrated systems support for all enterprise related functions including engineering, human resources, quality etc. and may additionally dynamically link to external customer and supplier chain systems.

Appendix D
Factors Retained in the Model

The three tables in this appendix indicate which factors should be retained or eliminated based on the keep-discard criteria established in Chapter 4. The second and third columns in these tables indicate our keep or discard recommendations. The fourth column is importance to customer needs as computed by the repair sector model, based on the relationship weights as assigned by LMI staff members. (This computed importance is independent of any actual repair sector evaluation.) The next column is the ordinal rank of each factor based on the computed importance. As examples, the first and second ranked factors are "incentive structure" (Table 4-4) and "customer knowledge" (Table 4-5). The lowest-ranked factor was "overhead structure" (Table 4-5). The sixth column indicates whether the factor evaluation depended on the repair sector being evaluated. As an example, "technology renewal rate" and "uniqueness of technology" (both in Table 4-3) do not. The next column indicates whether the evaluators understood the construct represented by the factor. LMI facilitators made this judgment. The two factors where problems persisted, even after sharpening the factor definitions and anchors, were "reserve capacity for this work" and "capacity in excess of workload" (both in Table 4-5). The final column in each table explains our recommendation to retain or eliminate the factor.

Table D-1. Evaluation Factors Retained for Nature of Work

Factor name	Keep	Discard	Computed importance to user needs (0.10)	Ordinal ranking	Evaluation depends on sector being evaluated?	Construct understood by evaluators?	Evaluators able to obtain necessary information to perform evaluation?	Comments
Relative size vs. the marketplace		✓	1.3	26	No	Yes	Yes	Not helpful in differentiating between sectors, since size compared to marketplace is independent of sector choice.
Relative size vs. sources of repair	✓		3.8	13	Yes	Yes	Yes	Differentiates between potential sectors and relates to a number of key characteristics of sectors, including adequate capacity and capability, and scope and scale economy.
Demand predictability	✓		1.6	24	No	Yes	Yes	Does not differentiate between sectors; however, it is helpful in evaluating pipeline size and scope and scale economy. Normally based on OEM's projections if historical data are not available.
Design stability	✓		1.9	23	Yes	Yes	Yes	Evaluation may depend on sector and specific source of repair; e.g., an OEM may be able to incorporate more design improvements than a third-party source of repair or a government source of repair.
Technology renewal rate		✓	3.3	16	No	Yes	Yes	Not helpful in differentiating between sectors, since technology renewal rate is independent of sector choice.
Uniqueness of technology		✓	2.1	20	No	Yes	Yes	Not helpful in differentiating between sectors, since uniqueness of technology is independent of sector choice.
Repair process dependence	✓		2.6	17	Possibly	Yes	Not always	Uniqueness of repair process may not be fully understood unless evaluators have experience with similar systems.
Availability of engineering		✓	1.5	25	No	Yes	Yes	One of the lowest-weighted factors, and not helpful in differentiating between sectors. Also, the more pertinent factor, absence/availability of proprietary data, is addressed in the next factor.
Absence of proprietary data issues	✓		2.5	18	Yes	Yes	Not always	If proprietary data are required, it may be difficult for evaluators to accurately assess the impacts if they do not have access to the data.

Table D-2. Evaluation Factors Retained for Nature of Relationship

Factor name	Keep	Discard	Computed importance to user needs (0.10)	Ordinal ranking	Evaluation depends on sector being evaluated?	Construct understood by evaluators?	Evaluators able to obtain necessary information to perform evaluation?	Comments
Type relationship (flexible vs. inflexible)	✓		7.8	3	Yes	Yes	Yes	Differentiates based on different types of contractual and non-contractual relationships between the buyer and the provider of repair services.
Scope of relationship	✓		3.4	15	No	Yes	Not always	Does not differentiate between sectors, but assists in under-standing probable work packages. Evaluators, at times, had difficulty determining what items or sub-components were repa-rables.
Policy on related functions	✓		4.5	9	Yes	Yes	Not always	The organic sector evaluation is contingent upon whether the related functions are to be accomplished by the depot providing repair services or by other DoD activities.
Policy on lot sizes	✓		3.5	14	Yes	Yes	Yes	Some government evaluators believed this factor highlights a government sector policy disadvantage, i.e., batching of repa-rables.
Policy on repair parts	✓		5.8	7	Yes	Yes	Yes	The majority of government evaluators believed this factor would tend to favor the private sector.
Incentive structure	✓		9.6	1	Yes	Yes	Yes	Single most important factor; evaluators generally felt it would tend to favor the commercial sector.

Table D-3. Evaluation Factors Retained for Nature of Repair Sector

Factor name	Keep	Discard	Computed importance to user needs (0.10)	Ordinal ranking	Evaluation depends on sector being evaluated?	Construct understood by evaluators?	Evaluators able to obtain necessary information to perform evaluation?	Comments
Availability of alternate sources of repair	✓		7.2	4	Yes	Yes	Yes	The most important factor according to some interview comments.
Availability of sources with complementary workload	✓		3.9	12	Yes	Yes	Not always	Differentiates between potential sectors and relates to a number of key characteristics of sectors, including scope and scale economy, and reprioritization capability. Some evaluators had difficulty estimating the percentage of complementary workload.
Interest by potential sources	✓		5.0	8	Yes	Yes	Yes	In evaluating this factor, evaluators assumed that the government provided for necessary data.
Reserve capacity for this work	Provisionally		2.0	21	Yes	No	No	Evaluators were not able to frame the concept "reserve capacity" in a way that produced stable evaluations.
Capacity in excess of workload	Provisionally		2.4	19	Yes	No	No	Evaluators were not able to frame the concept "excess capacity" in a way that produced stable evaluations.
Availability of skilled labor	✓		4.4	10	Yes	Yes	Yes	Differentiates between potential sectors and addresses a number of key characteristics of sectors.
Overhead structure		✓	0.4	27	Yes	Yes	No	Evaluators had difficulty determining accurate responses, particularly if a single potential SOR was not identified. Lowest weighted factor.
Stable labor relationships	✓		1.9	22	Yes	Yes	Yes	Most private-sector evaluators believed this factor would tend to favor the organic sector.
Customer knowledge	✓		8.1	2	Yes	Yes	Yes	Differentiates between potential sectors and is the second most heavily weighted factor.
Product knowledge	✓		4.4	11	Yes	Yes	Yes	Differentiates based on sector's understanding of product to be repaired.
Repair process knowledge	✓		5.8	6	Yes	Yes	No	Evaluators' responses generally reflected the uniqueness of the item to be repaired (i.e., if item was unique, then evaluators would tend to score process knowledge lower than if not unique).
MRP-II-consistent management methods	✓		6.2	5	Yes	Yes	No	Requires evaluators knowledgeable in MRP-II methods.

Appendix E
Abbreviations

AHP	analytic hierarchy process
CCFD	Cockpit Control Feel and Drive
DTA	decision tree analysis
FLIR	forward-looking infrared
IPT	integrated process team
LCC	life-cycle cost
LMI	Logistics Management Institute
MAUT	multiattribute utility theory
MRP-II	manufacturing resources planning
OEM	original equipment manufacturer
QFD	quality function deployment
RSS	repair sector selection
SOR	source of repair
SPO	system program office

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13. ABSTRACT (Maximum 200 words)

The process used by the Department of Defense to decide whether the public or private sector should perform depot-level maintenance has proven less than satisfactory. Both internal and external critics continue to call into question the comprehensiveness, consistency, and fairness of the process, as well as its effectiveness in mitigating performance risk. Additionally, historical rules of thumb have become suspect or controversial or both.

We developed and recommend for use a new model of the repair sector selection (RSS) decision that incorporates needs of the end users of depot repair services (e.g., timeliness, low cost, and quality); characteristics of the two repair sectors such as adequate capability and capacity, scope and scale economy, and responsiveness that affect their ability to satisfy user needs; and factors that determine the characteristics of the repair sectors. We also developed a companion decision process as a means to apply the decision model fairly and consistently. To operate the process, we recommend the creation of an RSS decision support cadre reporting to the Defense Depot Maintenance Council.

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